G.E.C. Journal

VOL. XIV. FEBRUARY, 1947 No. 3

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APPLICATIONS OF RADIO TECHNIQUE TO GENERAL MEASUREMENTS – – 167

By G. R. Polgreen.

Published by

THE GENERAL ELECTRIC Co., LTD.

Magnet House, Kingsway, London, England.

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NIGHT VIEW OF FLUORESCENT STREET LIGHTING IN BROMPTON ROAD, KENSINGTON.
This installation employs 80 watt fluorescent lamps. Ten lanterns, each containing seven lamps, are installed over a distance of 220 yards and arranged in the manner shown in the illustration.

Electrical Progress and Development.

Contributed by Members of the Technical Staff of the Works and Research Laboratories of the Company.

INTRODUCTION.

EARLIER reviews of Progress and Development* have necessarily been concerned mainly with work directly connected with the war effort, which absorbed virtually the entire capacity of the organisation for six years. By contrast, the present survey now looks to the present and even more to the future. The difficult period of transition from war to peace is not yet ended, but already it is possible to distinguish future trends and to plan accordingly. It is obvious that an enormous amount of material must be produced to re-equip home industries and a simultaneous effort is necessary not only to regain old markets abroad but to capture new ones.

In the present article some account is given of the power plant needed to augment generating capacity, and in this connection special interest attaches to the equipment being built for the Scottish Hydro-electric Board. Further electrical ship propulsion gear is in hand and a new type of smoke detection equipment for marine use has been produced and is already installed on H.M.S. *Vanguard*.

Rectifiers of unit construction have been supplied to industry, for traction work and, for the first time, for overseas installations. Much progress has been made in the field of traction, the order for Belfast City Transport Department constituting one of the largest fleets of trolley bus equipments to be supplied by one manufacturer anywhere outside the London Passenger Transport system.

The applications of electronic control are becoming continually more diverse; several industrial types have already been supplied and a number are in course of completion.

Much valuable work has been done in the matter of protective gear and the use of telephone type relays in connection with power supply systems represents an important innovation.

A great deal of ingenuity has been displayed in designing special equipment for use in many G.E.C. factories to increase the speed and efficiency of manufacture.

Important advances in lighting technique are apparent in almost every field, the adaptation of the fluorescent lamp to street lighting and for use in hospital operating theatres being notable examples. Many special types of lamp are proving particularly suitable in meeting the exacting demands of the cinema industry.

The legacy of the intensive work undertaken by the Research Laboratories, Wembley, during the war, on valves and radio communication is now available for normal peacetime uses. Much has been done already to increase the safety of commercial aviation at night and in foggy conditions and very much more can be expected in the near future.

POWER EQUIPMENT.

Hydrogen Cooling of Turbo-Alternators.

Although hydrogen cooling for self-contained units such as synchronous condensers has been in successful operation in the United States for a number of years, its use for large turbine driven generators did not become general until the early war period. The success of these installations has been such that American Standard specifications have been issued for machines with outputs as low as 11,500 kVA at speeds of 3,600 r.p.m. In Great Britain development was held up owing to the war and it is now necessary to make up this leeway.

The primary advantage of hydrogen cooling is the very marked reduction in windage loss. The density of pure hydrogen is approximately 1/14 that of air which results in an effective windage loss of only 10 per cent of that with air. In particular, on the rotors of large diameter required by alternators of very large output operating at 3,000 r.p.m., the windage loss may represent over 50 per cent of the full load losses in an air cooled machine; with hydrogen cooling the reduction of these losses represents a gain in efficiency of up to 1 per cent.

In two most important respects hydrogen has superior cooling properties: its thermal conductivity is 7 times that of air and its capacity for carrying away heat from a given surface is markedly better than that of air.

* "Electrical Progress and Development," *G.E.C. Journal*, Vol. XIII., No. 3, 1945, and Vol. XIV., No. 1, February, 1946.

This installation employs 80 watt fluorescent lamps. Ten lanterns, each containing seven lamps, are installed over a distance of 220 yards and arranged in the manner shown in the illustration.

As a result, greater output can be obtained with the same active material. In the present state of development the gain is some 20 per cent in output, but it is probable that with further experience, and by the use of hydrogen at high pressure, this figure may be raised further.

Other advantages accruing from the use of hydrogen are that the effect of corona on insulation is rendered negligible and the insulation retains its flexibility longer, thus extending the life of the machine. Further, as hydrogen will not support combustion, fire hazard is minimised; and owing to the complete gas tight enclosure, dirt and moisture are excluded, resulting in a cleaner generator requiring less maintenance. The machine also runs more quietly owing to the heavy casing and reduced windage loss.

Since mixtures of air and hydrogen are highly explosive over a very wide range, it is necessary to use hydrogen of a degree of purity above 90 per cent within the casing. However, in order to ensure complete safety in case of misuse, the whole external casing of the alternator is made explosion proof.

To couple the alternator to the steam turbine the shaft has, of course, to pass through the casing, and the seal necessary to prevent the escape of hydrogen is of paramount importance. Investigations are being actively pursued on the design of the seal and casing as well as on the apparatus for indicating the purity of the hydrogen and for purifying the oil used in the seal. During the operation of filling with hydrogen, or expelling the hydrogen from the casing, intermediate scavenging with an inert gas, carbon dioxide, is introduced.

Turbo-Alternators and Compressors.

Of the many large turbo-alternators for the re-equipment of central stations at home, a 37,500 kVA unit has recently been installed at the Sculcoates Station, Hull, and another of the same capacity is being installed at Woolwich; while of the four 35,300 kVA sets on order for the Meaford Station of the West Midland Joint Electricity Authority, two are in course of erection at the site. For Newport Corporation, a further set, rated at 37,800 kVA, is at present in course of construction.

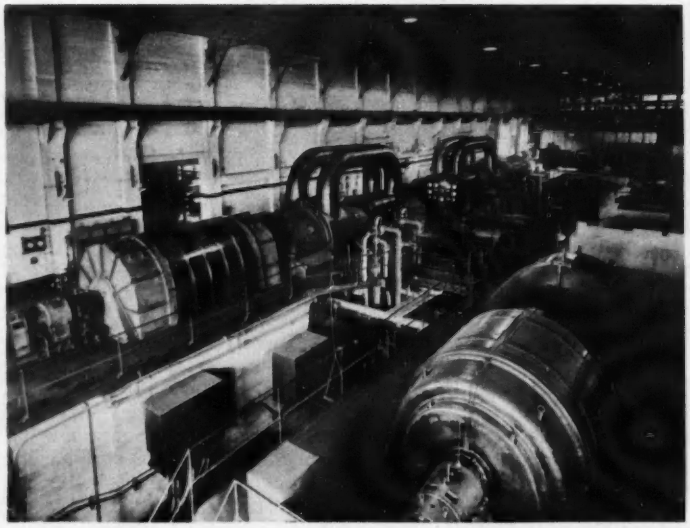


Fig. 1. Three 37,500 kVA, 22 kV turbo-alternators in the Power Station of the Woolwich Borough Council; the two on the left are in service, a third is in course of erection. An earlier set, rated at 15,000 kVA, is seen in the right foreground.

A number of turbo-generating units are also being built for Overseas users, including one for Haifa Power Station, Palestine Electric Corporation. This is a 40,000 kVA, 11 kV unit running at 3,000 r.p.m., with a separately driven exciter set. An 860 kW alternator for supplying the auxiliaries is directly coupled to the main turbo-alternator shaft.

A further order for two 37,500 kW units for the Orlando Power Station, Johannesburg, has been received, making a total of five machines in all for this station.

Amongst other export orders at present in hand there are a 12,000 kW set for the Reading Station; a 7,500 kW set for Bloemfontein Municipality; a 7,500 kW set for Patna, India; a 4,400 kW set for the Indian Copper Corporation, and two 7,500 kW sets for the State Electricity Commission of Queensland. There are also a number of motor driven air compressors for South Africa of capacities up to 20,000 cubic feet per minute and delivery pressures of 85 lbs. per sq. in.

Scottish Hydro-Electric Board, Errochty Power Station.

An order has been received from the North of Scotland Hydro-electric Board for three vertical shaft waterwheel alternators for the Errochty Power Station in the Tummel Garry Scheme. Each alternator is rated at 27,800 kVA C.M.R., 11,000 volts, 50 cycles, 3 phase, .9 power factor, but is to be capable of operating at any voltage between −15 per cent and +10 per cent at the normal rating. The turbines are of Boving manufacture, rated at 35,000 h.p. against a 525 ft. head of water and will drive the alternators at a normal speed of 428 r.p.m., the mechanical design, however, being adequate to deal with an overspeed of 810 r.p.m.

The alternators are direct coupled to the turbines, as are also the main and pilot exciters as well as the permanent magnet alternator which supplies power for the turbine governor control. A closed system of ventilation is employed, the air being cooled by eight separate water cooled units mounted round the periphery of the alternator frame. A Michel thrust bearing above the rotor carries the entire weight of all rotating parts together with the hydraulic thrust of the turbine.

The Company is acting as main contractors, the consulting engineers being Merz & McLellan; the order includes all requisite auxiliary equipment both for the water turbines and the generators.

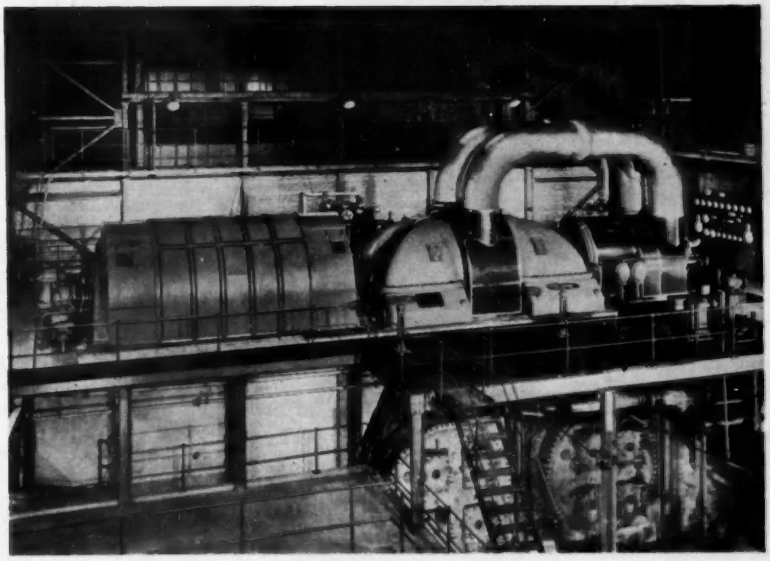


Fig. 2. A 37,500 kVA, 22 kV G.E.C. turbo-alternator in the Sculcoates Power Station, Hull.

Synchronous Condenser for Palestine.

A large synchronous condenser for installation in the Reading Power Station has recently been completed (fig. 3). The condenser is rated at 10,000 kVA, 6·3/6·9 kV, 50 cycles, 3 phase, 1,000 r.p.m., and is designed primarily for operation at zero leading power factor for the purpose of correcting the power factor of the load on this station, which consists mainly of a large number of small motors driving irrigation pumps. The machine is started by means of a 500 h.p. synchronous induction

pony motor mounted on the same bedplate as the condenser and directly coupled to it. Excitation for the pony motor is derived from its own exciter which is driven direct from the main shaft.

The condenser is also required to provide 4000 kVA at zero lagging power factor under certain conditions of the network when only a small load is connected. For this purpose a pilot exciter is provided in addition to the main exciter so as to maintain stability of excitation. These two exciters are mounted at the end of the condenser remote from the starting motor, all the machines being accommodated on the one bedplate. The condenser is also required for occasional use as a generator for short periods to provide power for testing cables and transformers. For this purpose it is driven by the pony motor and gives an output of about 350 kW.

In view of the atmospheric conditions on site the condenser is cooled on a closed air circuit system, air being circulated by fans on the rotor shaft through suitable trunking and passing through two water cooled tubular air coolers. The pony motor is also connected in the air circuit, while the main exciter has its own closed circuit system, embodying a heat-exchanger incorporated in the bedplate; the remaining machines are all totally enclosed.

The starting and running of the set is arranged for remote control, and the equipment includes all auxiliaries, automatic regulators, oil and water pumps, instruments and switchgear.

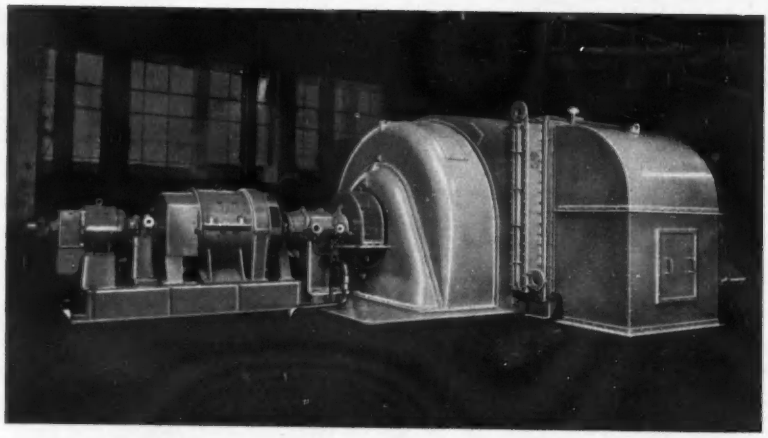


Fig. 3. 10,000 kVA synchronous condenser for the Reading Power Station, Palestine Electric Corporation.

Transformers: On-load Tap Changing.

The new type "J" on-load tap changing switch has been designed for use on 132 kV transformers with earthed neutral, to the C.E.B. Specification, also with 66 kV fully insulated transformers, and with the larger sizes of 33 kV transformers. A view of this switch attached to the 20,000 kVA, 132 kV transformer supplied to the C.E.B. for installation at Fraddon is shown in fig. 4.

The switch has been designed for transporting attached to the transformer, the whole equipment coming within the standard railway loading gauge. The resulting convenience and economy of labour in erection are distinct advantages. Though compact, the switch is easily accessible for maintenance purposes, as can be seen by fig. 5.

Several novel features are embodied in the construction. Selectors, diverters, driving mechanism and distribution shaft units are manufactured as individual sub-assemblies, and after being mounted in the tank are mechanically coupled together by flexible drives. This obviates any possibility of binding during operation which might result from strains occasioned in transport.

The selectors operate upon a patented eccentric motion in which moving contacts engage and disengage fixed contacts in the desired order with a minimum of effort. On the diverters, arc control pots are provided similar to those used on oil circuit breakers for the arcing contacts.

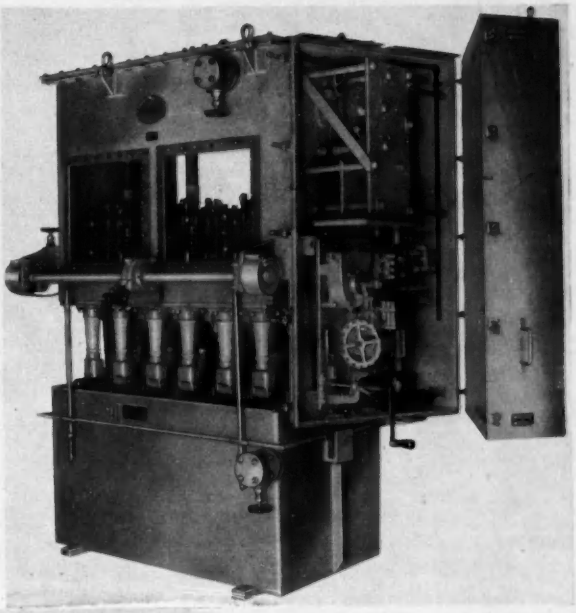
The entire mechanism has been subjected to very searching tests, both electrical and mech-

anical. Further orders for this switch have been received from the Central Electricity Board, Welwyn Garden City, and for overseas use.

MERCURY ARC RECTIFIERS.

The demand for mercury arc rectifiers for normal industrial uses has increased very considerably since the end of the war. An interesting development has been the wider application of the unit construction type comprising rectifier, switchgear and transformer on a common base. This arrangement was originated by the G.E.C. especially for industrial applications but is now employed for traction substations. The company has also taken the lead in supplying the first rectifier of unit construction for overseas work.

The success of the standard cubicle arrangement of the pumpless steel tank rectifier in the steel industry has resulted in repeat orders, such as that for the English Steel Corporation, for whom seven 920 kW 4000 ampere units have been installed. Other interesting applications of this type have been a 300 kW single cylinder unit supplied to Bournemouth Gas Company, two 250 kW units for the Accra Water Works, and a 600 kW unit for boiler house auxiliary supplies in one of the Southern Railway Company's power houses. The successful application of grid control rectifiers is confirmed by repeat orders from a variety of users, such as the Newport Corporation, while a special innovation has been the construction of a demonstration unit for the Sydney Technical College in Australia. This unit, with all grid control gear housed in a single cubicle, was designed with suitable connections and links to permit of the metering of the important parts of the circuit for purposes of demonstration, and with facilities for operating the grid controlled rectifier as an inverter.



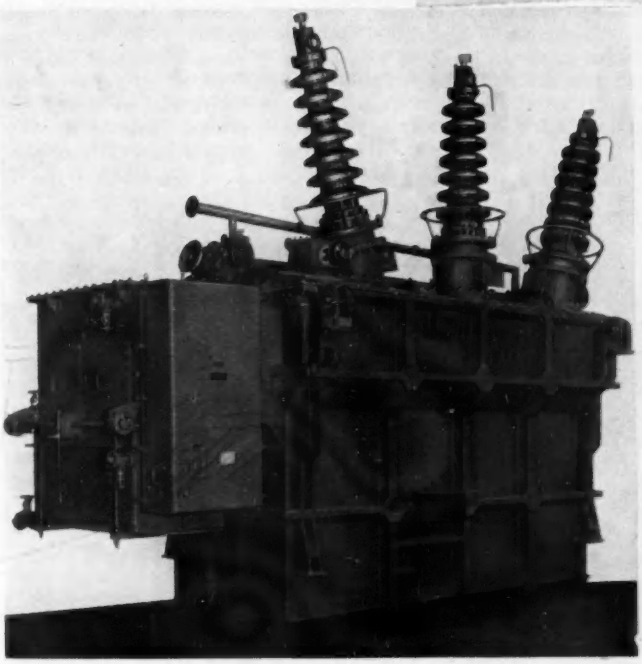


Fig. 4 *(left)*. **Tap changing switch on the 20,000 kVA, 132/33 kV transformer at the Fraddon Station of the C.E.B. Fig. 5** *(above)*. **The new type "J" on-load tap changing switch, showing operating mechanism, on a 10,000 kVA, 33 kV transformer for Welwyn Garden City.**

The termination of the war has seen the conversion of a number of mobile units to permanently housed substation equipments, and it is worthy of note that the adaptation to the new environ-

Fig. 6. Two 2,000 kW 630 volt steel tank pumpless air cooled rectifier equipments at the Bow substation of the London Passenger Transport Board.

ment has been made without appreciable modification. Similarly, a number of war-time installations have been modified for output voltages to suit peace-time uses. An important event has been the bringing into service of the first three substations on the eastern extension of the London Transport underground system, involving substations at Bethnal Green, Bow (fig. 6), and Leyton. These substations are each equipped to supply 2000 kW at 630 volts and represent the first of the nine 2000 kW and thirteen 1500 kW pumpless rectifiers being installed in this section of the main traction service of London Transport.

An order has been placed by the Dutch State Railways for two 1200 kW mobile rectifier substations to be used for providing power to the electrified lines in Holland.

It may be remarked that the G.E.C. supplied the first British built water cooled rectifier to the Continent, the first steel tank, pumpless, air cooled rectifiers, and have now similarly received this order for the first British mobile rectifier substation to be installed on the Continent.

TRANSPORTATION.

TRACTION.

As might have been expected at the conclusion of the war, attention has been largely directed to the question of urban passenger transport.

Of the 114 regenerative trolley bus equipments ordered for the Belfast City Transport Department, only 88 had been completed at the outbreak of war. As a result of the excellent performance of these under the abnormally severe conditions of the last seven years, 24 further regenerative equipments have been ordered. All these are mounted

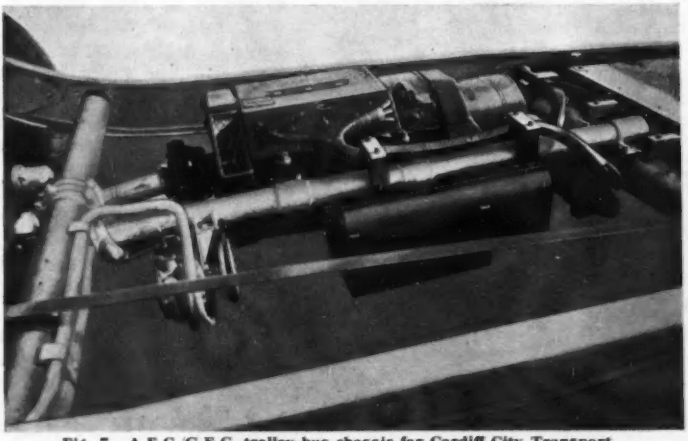


Fig. 7. A.E.C./G.E.C. trolley-bus chassis for Cardiff City Transport, showing motor with air filter.

on A.E.C. chassis, and it is worthy of note that an additional 70 equipments for use with Guy Motors chassis have also been ordered. These latter are to be of the non-regenerative type, the general scheme being very similar to that

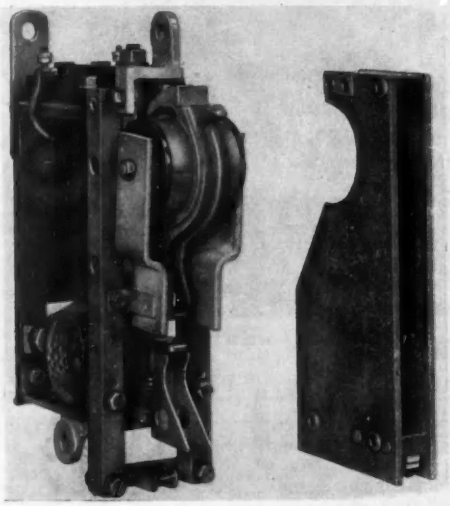


Fig. 8. Main contactor for trolley-buses for Cardiff City Transport.

employed at Cardiff, as described later, except that no appreciable degree of regeneration is possible at normal road speeds. Virtually all this equipment is of the new design detailed in connection with that contract. It is of particular interest that, on the completion of these orders, there will be 182 electrical equipments operating in Belfast, constituting one of the largest fleets of trolley buses equipped by one manufacturer anywhere outside the London Passenger Transport Board's system.

An early order was received for the Cardiff City Transport Department for 65 trolley-bus equipments following 10 such equipments previously ordered, but not completed owing to the war. The new equipment is based on a compound motor scheme designed for a limited regenerative characteristic associated with rheostatic braking. This is a system long advocated by the Company, and now being adopted almost universally. It possesses the advantage of avoiding any appreciable regeneration of energy to the line and hence of the high voltage troubles sometimes experienced with regeneration. The torque characteristic of the rheostatic braking is such that the back tractive effort does not endanger the rear axle.

Several new features developed during the war are worthy of note: the motor is constructed so as to be floodproof up to the base of the shaft, and a combined air filter and dust settling tank is provided for the ventilating system of the motor (fig. 7). The filter is constructed on the dry cyclone principle, such that virtually all dust is deposited in the settling tank instead of being drawn into the motor. Being of the dry type there are no oily surfaces to become clogged with dust, nor can oily vapour be drawn into the motor. Other notable advantages are: highly efficient dust collection, less brush wear due to absence of dust on commutator and brushes, a cooler running motor in service due to unobstructed air ducts, and reduced maintenance.

The contactors controlling the motor are also of a new design which gives longer life to all mechanical parts. Simplicity of design and reduction in weight are two further features of this contactor which is shown in fig. 8 with the arc chute removed. Corresponding improvements have been made in the design of the master controller and reverser (fig. 9). Other equipment, such as relays and trolley change-over switches, have been completely re-designed.

As yet there has not been time to resume work on all the suburban electrification pro-

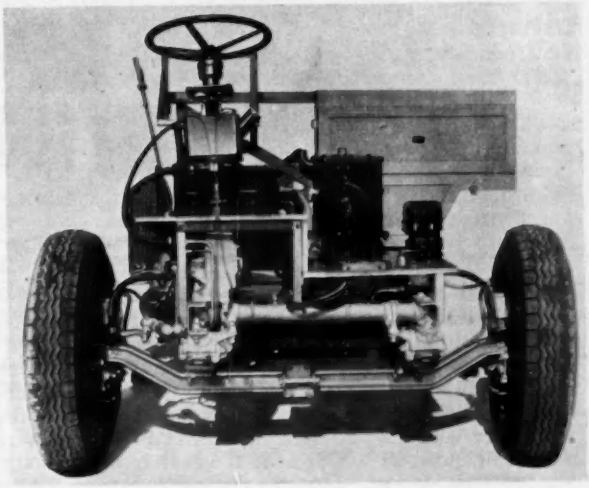


Fig. 9. A.E.C./G.E.C. trolley-bus chassis for Cardiff City Transport, front view showing controller and controller case.

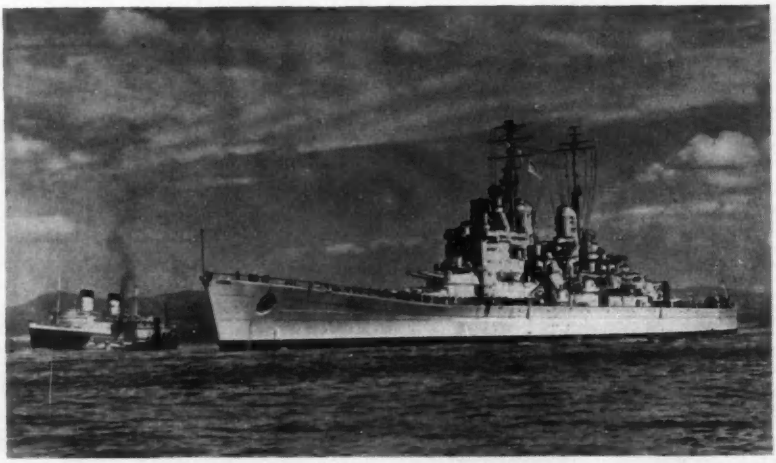


Fig. 10. H.M.S. "Vanguard," the latest capital ship of the Royal Navy, in which is installed a smoke detection and indicating equipment.

jects planned before the war, but considerable development is in hand, and the designs for the multiple unit stock on order for the L.N.E.R. Manchester-Glossop electrification are being revised in accordance with latest practice.

Other developments include a new cam shaft controller for multiple unit stock, based to some extent on the experimental multi-notch equipments produced for London Transport before the war.* A new cam shaft controller for multiple unit stock is in course of development.

In view of the big demand from overseas very careful study has been given to the design of diesel electric drives for locomotives and motor coaches, and suitable schemes are being standardized, which include generators and auxiliaries, as well as the special apparatus necessary. Particular attention has been paid to the important question of control.

In the matter of main line electric locomotives the demand has not been particularly great since the end of the war. Despite this, a number of special schemes has received very detailed investigation, particularly as regards 1500 volt and 3000 volt equipment.

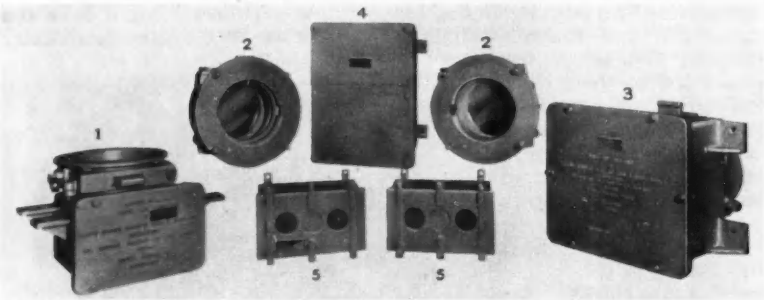


Fig. 11. Components of smoke detector equipment.
1. Projector lamp. 2. Reflecting mirrors. 3. Photocell amplifier. 4. Control box. 5. Indicating lamp boxes.

Electrical Ship Propulsion.

Following the construction of electrical propulsion equipment for four heavy lift cargo vessels built by the Greenock Dockyard,† an order has been received from the Eagle Oil & Shipping Co., for a similar equipment for a new single screw tanker. The propulsion motor is a 3·2 kV salient pole machine rated at 9,000 s.h.p. at 124 r.p.m., and is supplied by a

* "An Experimental Multi-Notch Control Equipment for London Transport Tube Railways," by E. H. Croft, *G.E.C. Journal*, Vol. VIII., No. 3, August, 1937, p. 177.

† "Electrical Progress and Development," *G.E.C. Journal*, Vol. XIV., No. 1, February, 1946, p. 22.

turbo-alternator giving an output of 6940 kW at 3220 r.p.m., 53·8 cycles. Both the propulsion motor and turbo-alternator are ventilated by means of a closed circuit system which includes the necessary fans and air coolers. A 400 kW D.C. geared turbo-generator running at 1000 r.p.m. supplies auxiliary power at 220 volts. The switch and control gear are to be substantially similar to that provided for the earlier contract.

Smoke Detection Equipment.

Fuel economy is a matter of national importance at the present time. Coal output is barely sufficient for essential needs, a fact that has laid stress on the use of fuel oil wherever possible. In view of this, the photo-cell smoke detector and indicator recently developed is a matter of more than passing interest. The purpose of this equipment, which has been designed in conjunction with the Admiralty primarily for marine use with oil fired boilers, is to give the operator controlling the air and fuel valves immediate indication of the existence of a smoky condition of the uptake.

The equipment has already been installed on the aircraft carrier H.M.C.S. *Warrior*, and on the latest battleship H.M.S. *Vanguard*, in which the Royal family travelled to South Africa (fig. 10). On both these vessels it has been tested with success.

The use of a photo-cell supersedes the obsolescent method of gauging visually the condition in the uptake by observing a beam reflected from a mirror. It was not always easy to detect a change promptly, and control became erratic. The photo-cell installation entirely overcomes such difficulties since the indicating lamps adjacent to the controls instantly show any change in smoke conditions, even before the smoke reaches the top of the funnel, and enable the operator to make the necessary adjustments. This immediate response makes possible a clear funnel at all times and results in a large saving in oil, especially on long voyages.

The equipment consists essentially of a lamp house containing a 12 volt 36 watt bulb which projects a ray of light across the boiler uptake on to a mirror which reflects it on to a lens by which it is focused on to the cathode of a photo-cell contained in an amplifier (fig. 11). The number of mirrors may be increased according to the size of the uptake. The various components are attached to the uptake of the funnel as close as practicable to the boiler so as to obtain the earliest possible indication of any change in combustion. The projector lamp-house, mirrors and amplifier are each protected by armour plate glass which prevents their oiling up under working conditions. These glasses are easily removable for cleaning. The control box, containing the constant voltage current transformer and calibrating resistances, is usually placed in the main engine control room.

There are two indicating lamp boxes for each uptake, one in the boiler room and one for the information of the shift engineer. Each has three coloured glasses: green indicating a clear funnel; yellow, a slight haze; red, excessive smoke. Normally, therefore, the operator will ensure that the indication is always green, or, at least, hovering between green and yellow.

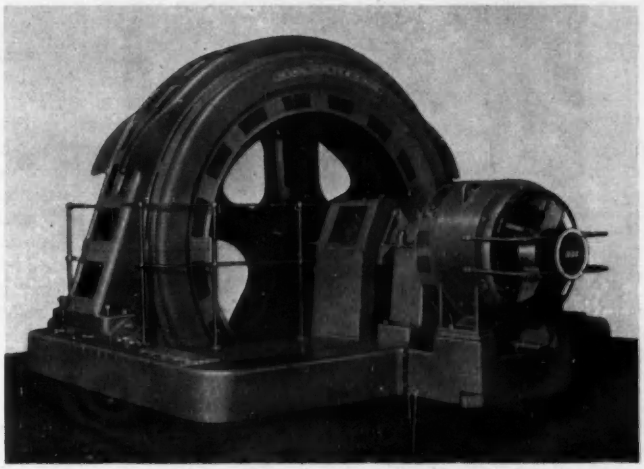


Fig. 12. 1,500 h.p., 2.2 kV, 120 r.p.m., salient pole synchronous induction motor supplied to the Government Gold Mining Areas, Modderfontein, to drive a ventilating fan.

Mining Gear.

A great variety of mining equipment for home and overseas use has been manufactured during the last year and considerable contracts are still in course of completion.

A large synchronous induction motor of the salient pole type has recently been supplied to the Government Gold Mining Areas

(Modderfontein) Consolidated, for driving a ventilating fan (fig. 12). The machine is rated at 1500 h.p., 2200 volts, unity power factor and runs at 120 r.p.m. The fan which is 30 ft. in diameter was originally driven by a steam engine.

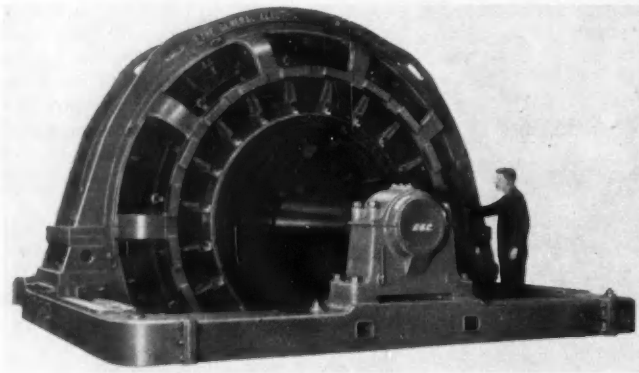


Fig. 13. A 2,140 h.p. 650 volt D.C. winder motor, operating at 57 r.p.m. for the Crown Mines, Johannesburg.

For the Crown Mines, Johannesburg, there has recently been completed a compensated D.C. winder motor of 2140 h.p., 650 volts, 57 r.p.m.; the peak rating being 4075 h.p. (fig. 13). The motor is supplied from a Ward-Leonard set comprising a 1700 kW D.C. generator driven by a 1800 h.p., 2200 volt slipring induction motor at 500 r.p.m.

A colliery electrification scheme for the Welsh Navigation Collieries Co., Ltd., includes two A.C. winders, two compressor drives, a 33 kV outdoor substation, together with transformers and main switch and control gear; the mechanical equipment is being manufactured at Erith Works, and the electrical gear by Witton Engineering Works.

The upcast shaft winder comprises an ordinary cylindro-conical drum driven through reducing gears by a 3·3 kV 700 h.p. slipring motor which raises a useful coal load of 48 cwt. from a depth of 2,019 ft. In the downcast shaft it is necessary to wind alternately from two different depths of 1,131 ft. and 1,596 ft. respectively. For this purpose a special drum has been designed, one half of which is cylindrical and is used for winding from the shallower seam, the other half being cylindro-conical for winding from the lower seam. The drum is driven through reducing gears by a 1,350 h.p. slipring motor.

An interesting feature is the new design of horizontally operated liquid controller with oil actuated assister gear and an automatic acceleration controller.

Both winders are arranged for dynamic braking; the necessary power being derived from a separate motor generator set. The mechanical brakes, which are of the suspended caliper type actuated by an oil operated brake engine, are normally applied by oil pressure and not by weights as formerly.

The main transformers are of the outdoor type, each rated at 5,000 kVA 33 kV/3·3 kV, while the two compressors are each driven by 740 h.p. 3·3 kV salient pole synchronous induction motors, running at 250 r.p.m.

Further G.E.C. electric winder installations are being constructed for the Babbington No. 4 Pit and the Calverton No. 2 Pit of the B.A. Collieries, Ltd., Nottingham. Both hoists are driven through gearing by 3·3 kV slipring induction motors, the former by a 925 h.p., 490 r.p.m. machine and the latter by a 1,750 h.p., 240 r.p.m. machine. In each case the new horizontally operated liquid controller is being used.

The hoist at Calverton No. 2 Pit, which will be the fourth equipment to be installed at this Colliery in recent years, is to be used for sinking the shaft and ultimately for hoisting 10 ton skips from various levels, the greatest depth being 1,680 ft. This duty demands a special design of drum, Eventually double parallel drums 17ft. 6ins. by 7ft. wide will be fitted, but initially when sinking, one drum only will be installed. In order to obtain the required output of 400 tons an hour, when winding from 1,680 ft. the cycle has to be completed in 80 seconds, an extra 10 seconds being allowed for loading.

MATERIALS HANDLING.

Equipment of Cement Works.

As main contractors for the new Shimshon Portland Cement Works to be erected in Palestine, the Company will be responsible for the entire electrical equipment, including generating plant, electrical drives, cables, overhead lines, lighting, telephone exchange and electric clocks. The generating plant consists of ten diesel-electric sets giving a 3·3kV, 50 cycle, 3 phase supply; eight of the sets are rated at 855 kW and the remainder at

485 kW. The distribution will entail the provision of four 1000 kVA, two 600 kVA and three 250 kVA transformers, 3·3 kV/380 volts/220 volts. The main switchgear in the power house will be of the 3·3 kV S.V.D. type, while the provisional total of motors to be supplied for various drives numbers 150 slip-ring and squirrel cage machines ranging from 1 h.p. to 1100 h.p. and aggregating 9000 h.p.

An overhead line is being erected for transmission of power to the quarries and with these will be included all the equipment needed for distribution at the quarries.

Ore Bedding and Blending Plant.

A comprehensive ore bedding and blending plant employing the Robins-Messiter system which will probably be the largest of its kind in the country, is in course of installation at the Corby Works of Stewarts & Lloyds, Northamptonshire. While generally similar to that built for the Scunthorpe Works of the Appleby-Frodingham Company,* it will embody several new features based on the experience gained from the operation of the earlier installation.

The pre-eminent advantage of the Robins-Messiter system is its ability so to blend ores of varying composition as to obtain a substantially uniform product. This is of particular importance with such ironstones as are mined from the Lincolnshire and Northamptonshire deposits, which are extremely variable.

After crushing, the ores are screened and then passed to the "bedding" conveyors, whence they are discharged into any one of four storage piles. When required the ores are reclaimed by one of two reclaiming machines, each of which serves one of two ore piles.

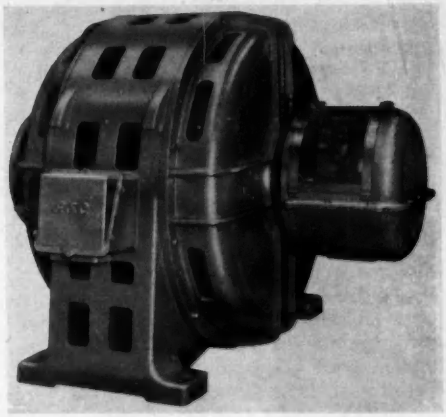


Fig. 15. 600 h.p. synchronous induction motor, 5,000 volts, 375 r.p.m., for rubber calender drive for the Dunlop Rubber Company's Speke Factory, Liverpool.

Conveyors then pass the ores from the reclaiming machines to storage bins. The maximum rate of handling is 600 tons per hour. Erith Works are responsible for the entire mechanical equipment, while Witton Works are supplying the necessary electrical gear. About 80 motors will be employed ranging from 5 h.p. to 100 h.p., the majority being A.C. machines with direct-to-line or rotor resistance starting.

The control panels aggregate a total length of 250 ft., and it will be appreciated that a very intricate sequence control is called for to ensure correct operation. An illuminated mimic diagram is being provided to enable the combination in use at any moment to be seen at a glance.

Jaw Crusher.

The development of large capacity power shovels has necessitated the manufacture of

* "Electrical Progress and Development," *G.E.C. Journal*, Vol. XI, No. 1, February, 1940, p. 16, *et seq.*

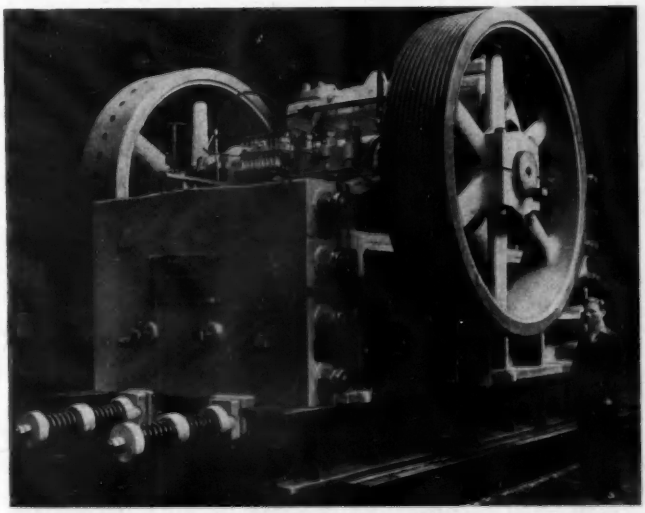


Fig. 14. A sledger with a jaw opening of 54 ins. by 42 ins. for use in a limestone quarry.

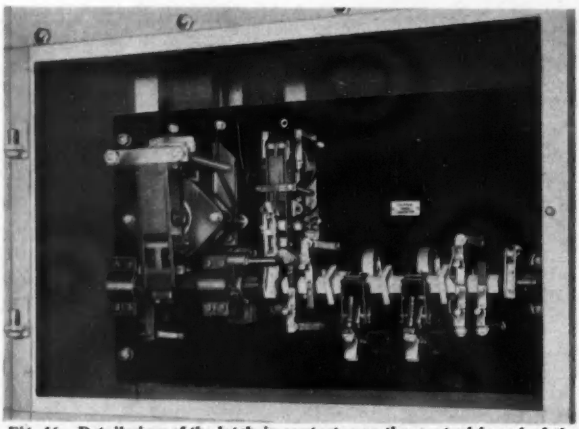


Fig. 16. Detail view of the latch-in contactor on the control board of the rubber calender drive at the Speke Factory of the Dunlop Rubber Company.

jaw crushers of correspondingly greater size. These large machines have the double advantage of an increased efficiency in rock breaking and economy in explosives and sledging. Crushers with jaw openings up to 72 ins. by 48 ins. have been designed by Erith Works. The accompanying illustration (fig. 14) shows a 54 ins. by 42 ins. sledger capable of dealing with 200 tons an hour, when reducing to a size of 8 ins., which has recently been supplied for use in a limestone quarry in South Wales.

INDUSTRIAL ELECTRIFICATION.

Electrical Equipment for Rubber Mills.

A considerable number of motors and associated sets of control gear have been manufactured for the Dunlop Rubber Company for installation in their Speke Works, Liverpool, and also for the New Zealand factory.

The motors are all alternating current machines ranging in sizes from 75 h.p. to 600 h.p., and voltages from 400 to 5,000 volts, and are required to drive rubber calenders, mixers and the like (fig. 15).

One of each of the 75 h.p. and 100 h.p. motors is a slip-ring induction motor, contactor controlled, arranged for quick stopping by means of plug braking initiated from a gravity controlled trip switch adjacent to the rubber machine. The motors, which run at approximately 730 r.p.m. are brought to rest in 7 to 8 revolutions. The remainder of the machines, about 30 in number, are of the synchronous induction type with separate exciter sets and are arranged to start against $2\frac{1}{2}$ times full load torque. By means of dynamic braking they can be brought to rest from a speed of 375 r.p.m. within $4\frac{1}{2}$ revolutions.

The larger low tension machines are of the inverted type, that is, the primary circuit is connected to the sliprings, while the starting equipment is connected to the stator terminals. The control gear comprises a primary switch which is an oil circuit breaker in the case of the high tension motors and a contactor for the low tension motors; the secondary starting equipment is of the time controlled contactor type. The exciter set is electrically interlocked to ensure that it is started first and must always be running when the main motor is running. As indicated, braking is effected from a gravity controlled trip switch adjacent to the rubber mill which when operated trips out the primary switch and closes a high-speed braking contactor which connects the motor primary terminals through a braking resistance (fig. 16). As the exciter is still connected to the secondary terminals this gives the effect of D.C. injected braking causing the machine to come to rest very rapidly. Five seconds after the motor has stopped running the exciter set is shut down under the control of a timing relay.

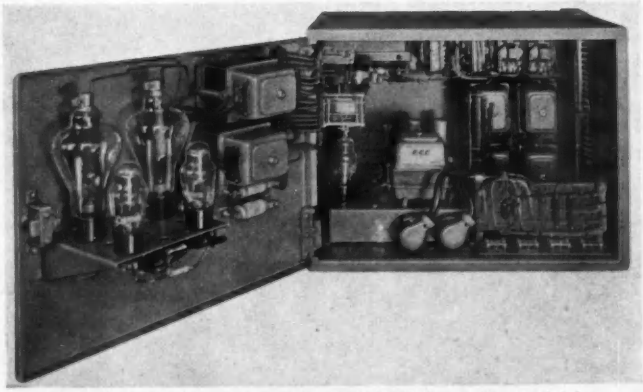


Fig. 17. Electronic motor control unit for D.C. machine tool drive.

Axle and Transmission Testing.

A complete electrical testing set has been designed for Humber Ltd., for the purpose of testing the back axles and transmission

gear of the larger sizes of car. The transmission shaft is driven by a 0/95 h.p. motor running at 3,500 r.p.m., the load on the road wheels being simulated by two 0/47·5 h.p. machines; losses are supplied from a 27 kW generator. The control gear, all of which is mounted in the desk, allows the following road conditions to be simulated :—

(i) Normal : engine driving road wheels.
(ii) Overdrive : road wheels driving the engine.

A complete test cycle comprises starting, acceleration to full speed (i), reduction of load and reversal to condition (ii), reduction of speed till the mechanism comes to rest. All this is effected by one complete turn of the main control wheel.

A balancing regulator enables the two road wheel motors to be run at the same or at different speeds, the latter setting being used to simulate cornering. By adjustment of the maximum field strength of the road wheel motors it is possible to accommodate axles of any gear ratio from 4·09:1 to 5·22:1. Provision is made for measuring the power input both to the axle when driving and to the road wheels when overdriving.

ELECTRONIC CONTROL.

Motor Control Gear.

A system of electronic motor control with special application to variable speed drives has been developed. In principle the scheme consists in operating a direct current motor from an alternating current supply through grid-controlled hot cathode rectifying valves, one set supplying a controlled adjustable voltage to the armature, a second set controlling the field of the motor. This system enables the motor to be run up to a pre-determined speed and to hold that speed sensibly constant over a wide range of load. It gives full protection against overloads in all circumstances. A number of these equipments has been supplied to B.S.A. Grinding Machine Co., Ltd. (fig. 17); others are on order for various industrial applications, including complete installations for use with apparatus being built in the G.E.C. Works.

Planer Drive Control.

An example of a typical industrial application is afforded by the control of the drive to a 5 ft. by 5 ft. by 14 ft. Loudon planer which is being installed at Witton Works. The main drive is from a 50 h.p., 480 volt motor, 620/0/620 r.p.m., the feed motor being a 7 h.p., 230 volt machine running at 750 r.p.m. Power is supplied at 400 volts, 3 phase, 50 cycles through a 6-anode grid controlled rectifier. The D.C. voltage, and hence the speed of the planer table, is controlled by varying the phase of the grid voltage through a static phase-shifting network. The amount of phase shift is controlled by an amplifier incorporating a number of "hard" valves. Reversal is effected automatically from the limit switches on the planer acting through the main armature contactors, the rectifier equipment automatically adjusting its phase to permit regeneration during the slowing down period. Emergency braking is provided to give rapid intermediate stopping when needed, and a mechanical brake is fitted to deal with failure of supply. An adjustable pre-selecting feed and maximum table speed controls are provided together with all the features usually associated with planer control.

Control of Lathe Drive.

A very interesting application of electronic speed control concerns the drive for a veneer peeling lathe which has been designed and built for the Forest Products Research

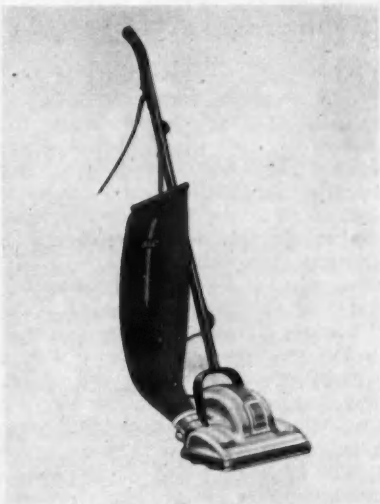


Fig. 18. The new vacuum cleaner displayed at the "Britain Can Make It" Exhibition.

Association, Ministry of Works. The lathe takes a log some 4 to 5 feet in length and strips it into a continuous sheet of veneer. For satisfactory operation the peripheral speed of the log must be kept constant and this requires that the rotational speed shall increase as the diameter decreases.

The equipment is the first of its kind in this country and comprises a 60 h.p., 230 volt, variable-speed D.C. motor with a maximum speed of 2,700 r.p.m. It is supplied from a Ward-Leonard set; speeds up to 900 r.p.m.

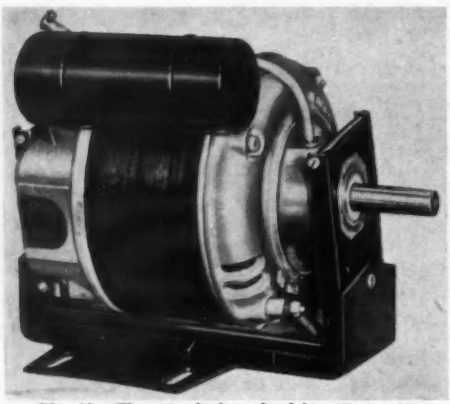


Fig. 19. The new design of refrigerator motor.

being attained by voltage variation and from 900 r.p.m. to 2,700 r.p.m. by shunt control. The motor generator set consists of a 100 h.p. slipring machine driving a 65 kW, 230 volt generator at 1,450 r.p.m.

The control equipment for the motor of the Ward-Leonard set and for the main driving motor is housed in two steel cubicles provided with the necessary isolators and interlocks. The lathe is controlled from a conveniently situated desk which carries start, stop and speed controls, instruments and indicating lamps as well as two speed indicators, one showing the rotational speed of the lathe, the other the peripheral speed of the log, that is, the veneer cutting speed. Remote "stop" buttons for emergency use are mounted directly on the lathe. The special feature is the double-speed control equipment which is of the electronic voltage-balance type and has two distinct functions: to hold constant (a) the rotational speed of the spindle while the job is being set up; and (b) the peripheral or cutting speed during actual working. Both of these requirements are achieved to an accuracy of 2 per cent.

ELECTRIC MOTOR DEVELOPMENTS.

Fractional Horsepower Motors.

The turnover from wartime to normal industrial production has made possible a number of innovations in the class of apparatus involving the use of small motors.

The new design of vacuum cleaner (fig. 18), was accepted for display at the "Britain Can Make It" Exhibition.

This new model includes a self-adjusting suction nozzle which automatically varies its position to suit the length of pile of the carpet which is being cleaned. The motor is resiliently mounted, the noise level is appreciably lower and the general performance of the cleaner distinctly better than that of pre-war models. A radio interference suppressor is now included as a standard fitment.

The refrigerator motor has been re-designed with regard for the existing stringency in the supply of sheet metal and cast iron. The opportunity has also been taken to improve its electrical performance, thus increasing still further the margin of safety allowed for compressor troubles and also rendering the motor capable of operating satisfactorily over a wider voltage range. A belt tensioning device has been provided in addition to the resilient mounting (fig. 19).

The motor of the hood type hair dryer used in hair-dressing establishments has also been re-designed, the chief characteristics being silence and reliability. It is now fitted with

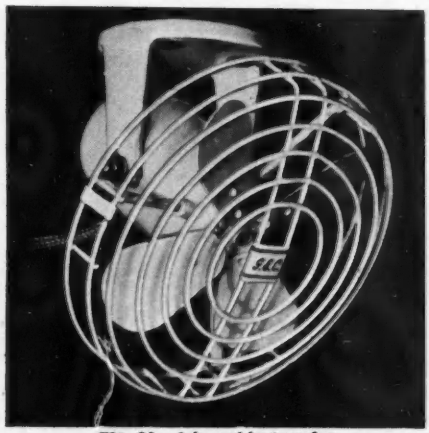


Fig. 20. 6 in. cabin type fan.

sleeve bearings and is arranged to operate satisfactorily at any angle of inclination.

The main improvement in the floor polisher concerns the construction of the driving discs which act as a frictional drive from the pulley on the motor shaft to the polishing brushes. The rubber tyres are now moulded directly on to the discs. A small but important modification has increased the reliability of the automatic switch which is operated by lowering the handle.

A new range of single phase fractional horse-

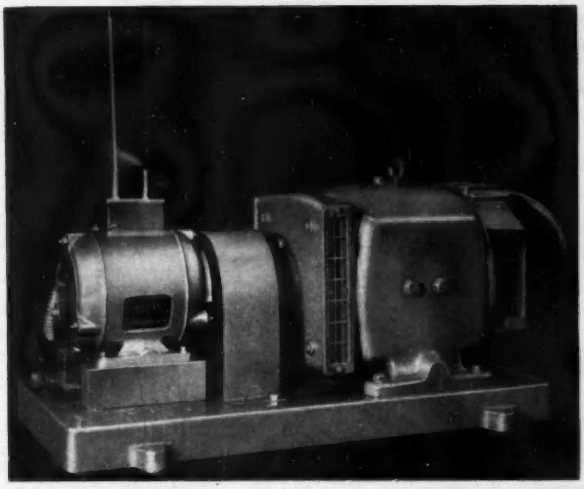


Fig. 21. Silicone insulated motor with a pan of water boiling on top of it. The small frame size of the motor is indicative of possible future trends.

power motors of ½ h.p., ¾ h.p., ·9 h.p., has been introduced. All these machines are suitable for capacitor starting, the ½ h.p. motor being also arranged for split-phase starting. In design it is similar to the refrigerator motor, but retains the steel shell while using die-cast aluminium brackets.

A special design of 4 inch and 6 inch fans has been developed for use in the cabins of aircraft and these are now in demand for the ventilation of sleeping bunks on shipboard, particularly in submarines. These fans are notably robust and compact, as can be seen in the illustration, fig. 20, and are wound for all voltages from 6 volts to 220 volts.

Silicones.

Investigations are in progress on the new Silicone-resin insulations which show that they are capable of withstanding high temperatures practically indefinitely. The use of this new type of insulation will mean that much greater outputs will be possible from machines of any given size.

An illustration of the heat resisting property of this insulation is seen in fig. 21, which shows an induction motor insulated in this way which is running continuously at a temperature of 130 degs. C. measured at the top of the casing, and that in the windings approaching 300 degs. C.

Glass Insulation.

Ever since fibrous glass insulation became available about the year 1938, it has been the aim of engineers to eliminate all vegetable fibrous material, such as cotton and press-paper, from electrical machines. In the early days the shortage of supplies coupled with high cost retarded progress; it was also necessary to make extensive tests of new varnishes to enable higher temperature machines to be designed.

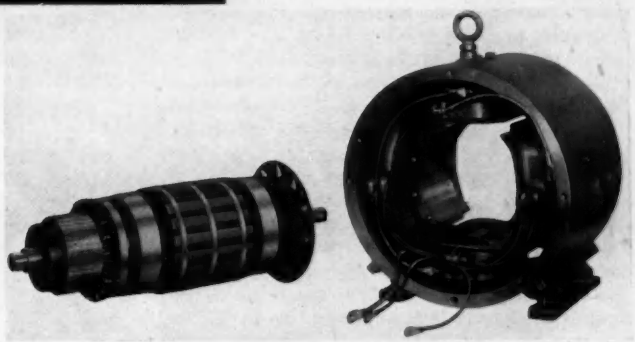


Fig. 22. 5 kW glass insulated generator.

The outbreak of war at first had the effect of bringing further development to a standstill, but later the necessity for an insulation which would be impervious to attack by various pests in the tropics and the importance of reducing weight for a given output revived interest in glass insulation.

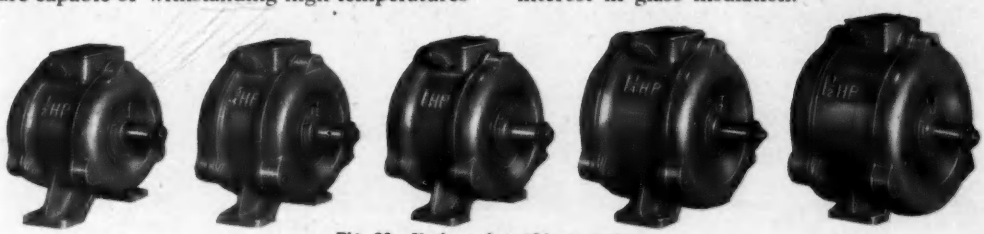


Fig. 23. Various sizes of loom motors.

In fig. 22 is illustrated one of several hundred 5 kW, 3000 r.p.m., 230 volt glass insulated generators designed to run at a maximum temperature of 140 degs. C. The insulation of the machine consists solely of glass, in various forms, micanite and special high-temperature varnishes.

Loom Motors.

In anticipation of the demands of the textile industry the range of loom motors has been largely redesigned. There are now seven ratings from ½ h.p. to 3 h.p. at 960 r.p.m. available. The more usual requirements are covered by the five sizes ranging from ½ h.p. to 1½ h.p. (fig. 23) and since the power necessary to drive a loom varies with the material being handled all five sizes have been designed to have the same centre heights and fixing dimensions, and are thus mechanically interchangeable, a matter of considerable convenience to the user. The 2 h.p. and 3 h.p. motors are similarly interchangeable.

The starting torque has been increased to three times full load torque so as to render the machines suitable for use with automatic looms.

A squirrel cage rotor of very simple and robust construction has been developed for the ½ h.p. and ¾ h.p. machines which are being produced in very large numbers. The ends of the copper bars, where they protrude from the slots, are bent over and fused together by means of an electric carbon arc, a mode of construction which is being extended to larger sizes as soon as practicable.

DEVELOPMENTS IN FACTORY EQUIPMENT.

The "Mutac" Switch.

Some indication of the work undertaken in the field of moulded insulation and the enormous output of these products during the war has been given in previous issues of the *G.E.C. Journal*.* In the course of the past year there has been a rapid return to manufacture for the normal requirements of industry, and as an example of this it may be of interest to describe one such typical product, the "Mutac" switch. This switch was designed before the war in conjunction with the Research Laboratories and has since been modified in the light of experience gained during the last seven years.

Reference to the switch has already been made in this Journal† and it will be sufficient briefly to recapitulate the main points of design. The switch is of the microgap type, suitable for use on A.C. circuits. The salient features are: silence of operation, small number of moving parts—three only; light loading of bearing surfaces giving long mechanical life, and silver contacts for electrical durability. The enclosure of all moving parts in a hollow case riveted to a sub-base, with an insulating gasket between them, prevents entry of dust or moisture. Under lengthy exposure to the worst tropical conditions the switch has continued to operate perfectly satisfactorily. The normal rating of the switch is 5 amps, but it has been authoritatively used at 10 amps. The range made before the war has been extended by the introduction of two more types for flush mounting.

* "Electrical Progress and Development," *G.E.C. Journal*, Vol. XIII, No. 3, February, 1945, and Vol. XIV., No. 1, February, 1946.

† "Electrical Progress and Development," *G.E.C. Journal*, Vol. XI., No. I., February, 1940, pp. 6 and 7.

Fig. 24. Automatic testing jig for the "Mutac" switch.

The production of the "Mutac" switch, which was naturally suspended during the war period, has now been established on a quantity basis. Output very soon reached high figures and, in view of the enormous demand for the equipment of new houses and for export, was rapidly expanded. During the course of the present year it is confidently expected that it will increase still further. Outputs on this scale can only be achieved on a regular programme by combining the most up-to-date design of moulding tools with modern methods of moulding technique, including the maximum degree of mechanisation. Exhaustive testing has played a major part in production, and considerable ingenuity has been employed in devising a suitable jig for automatic testing on the production line (fig. 24). Tests for four different kinds of faults are performed in rapid succession, namely, for open circuit, early break, failure to break and the dolly sticking. Red, blue, white and green lights respectively indicate the nature of the fault. Good switches are accepted into a chute while faulty ones are ejected. The entire operation occupies no more than a few seconds. The installation of this device has enormously accelerated testing and has eliminated errors due to faulty judgment on the part of the operator.

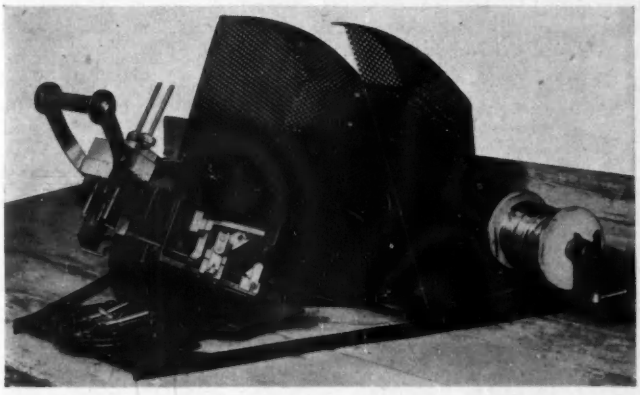


Fig. 25. Duplex arc soldering jig.

GENERAL FACTORY EQUIPMENT.

A great deal of work has been done by the Development Laboratory in designing special equipment for use in various factories to increase the speed and efficiency of manufacture. A few typical examples are briefly described below.

A duplex arc soldering jig built for the Moulded Insulation Works has been in use in the assembly line for some months. Its purpose is to enable a single operator to make two soldered tag connections simultaneously on a fan base regulator by merely pressing down a lever (fig. 25). A short length of resin-cored solder is automatically propelled forward over the tags and at the same time two carbons make contact with the tags, establishing a current which instantly raises the carbon tips to incandescence, thereby making the soldered joints. The speed of working is at least four times as fast as with hand soldering. This method has also proved more economical both as regards materials and power consumption. There is no idling time and power is on only at the instant of operation, whereas a soldering iron must be kept hot continuously.

In another section of these Works moulded insulation battery boxes are manufactured, and a self-contained portable testing equipment has been developed for checking the soundness of the insulating barriers between compartments. The barrier to be tested is sand-

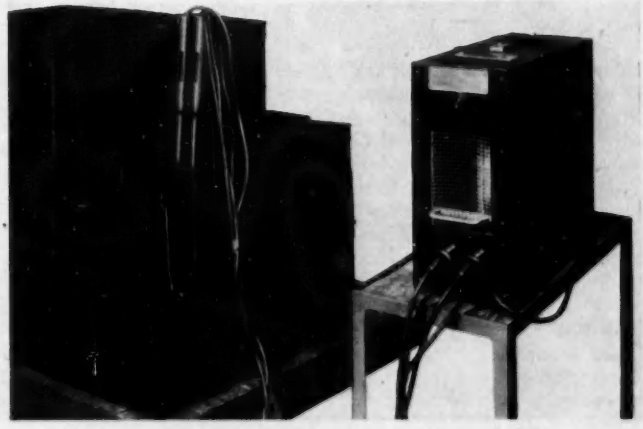


Fig. 26. Portable testing equipment for battery boxes.

wiched between flat electrodes excited from an induction coil interrupted by means of a rotary mercury jet switch (fig. 26). The electrode handles are each fitted with a switch of the "dead-man's-handle" type. The set has been in operation for about a year and has proved very much quicker and more convenient than the equipment previously used.

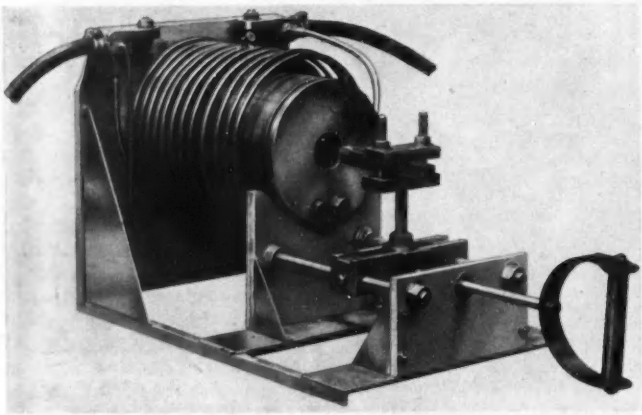


Fig. 27. Experimental high frequency induction tool tipping jig.

The tool tipping jig recently developed is an important application of high frequency induction heating. The jig, which is readily adaptable for various types of work, consists essentially of a high frequency step-down transformer with a single secondary turn. Due to skin effect the secondary current flows round the inner periphery of the turn and can thus be brought into close proximity to the work. In fig. 27 a tungsten carbide tip is seen in process of being brazed on to a cutting tool.

A most useful piece of apparatus in connection with the production of D.C. machines is one devised to clear short-circuiting particles from between the segments of commutators. The method employed is the application of a heavy impulse derived from a condenser. Several models have been made to cover every size of commutator. This device has been instrumental in saving a great deal of time since it clears instantly small particles of copper or other conducting material which it has been found extremely laborious to detect visually.

Most of the equipment in the Witton High Tension Laboratory was destroyed by enemy action early in the war, and in replacing this the opportunity was taken of greatly increasing the capacity of the surge generator, which now has a maximum output voltage of two-and-a-half million with a stored energy of 40,000 watt-seconds (fig. 28).

The generator is constructed in four columns comprising sixteen condenser units, each having a maximum charging voltage of 160,000 volts and a capacitance of 0·2 mfd. The standard surge voltage wave shape is 1/50 microseconds, that is, the voltage rises to its peak in 1 microsecond and falls to half value in 50 microseconds; but these values can be readily adjusted up or down through a considerable range. The output voltage is controlled by the inter-stage spark gap settings which are remotely adjusted by means of the motor driven central column.

For heavy surge current tests and on test objects having high capacitance and inductance, the sixteen condenser units can be readily reconnected with 2, 4, 8 or 16 stages paralleled during discharge. In this manner surge currents up to 90,000 amperes have been recorded.

Electrical Dynamic Balancing Machines.

An account has already been given in an earlier issue of this Journal* of the electrically operated

* *G.E.C. Journal*, Vol. XIII, No. 3, February, 1945.

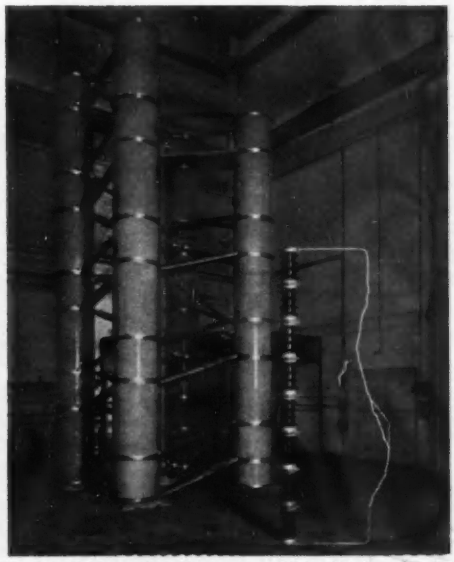


Fig. 28. High tension laboratory at Witton Works, showing two-and-a-half million volt discharge across an 8 ft. gap.

dynamic balancing machines developed and built for use in Witton Works. These were extensively employed during the war in connection with the manufacture of fractional horsepower motors; in all some 50,000 rotors were balanced by this means with complete success. One machine alone balanced ten thousand 8 lb. armatures to an accuracy of ·001 oz.-ins., while in another factory 10,000 fan motors for the Admiralty, of ratings up to 5 h.p., were balanced without a single reject.

A large machine is now being built to balance turbo rotors up to 40 tons in weight. In the accompanying illustration, fig. 30, initial tests on a prototype of this machine are seen with a 4-ton rotor. The leaf springs on which the bearings are suspended can be seen next to the vertical framework, enabling the bearings themselves to move in a horizontal plane and, by so doing, to produce electrical effects which after electronic amplification give meter readings proportional to the balance weights required. They also serve to operate instruments which determine the position at which these weights must be placed. The electronic apparatus is not shown in the illustration.

An idea of the greatly accelerated production resulting from the use of this machine may be gained from the fact that balancing operations which previously required several days can now be completed in an hour.

Cathode Ray Rotor Tester.

The general principle of the rotor tester is similar to that of the armature tester previously described*; the present machine, however, is adapted to test squirrel cage rotors which it would be impossible to test in any other way. Briefly, the method employed is to rotate the rotors in proximity to a special field magnet which develops a secondary current proportional to the currents produced in each rotor bar (fig. 29). As before, a peaked wave is thrown on the screen of a cathode ray tube, a faulty bar being indicated by a departure of the amplitude of the corresponding peak from the normal.

* *G.E.C. Journal*, Vol. XIII, No. 3, February, 1945.

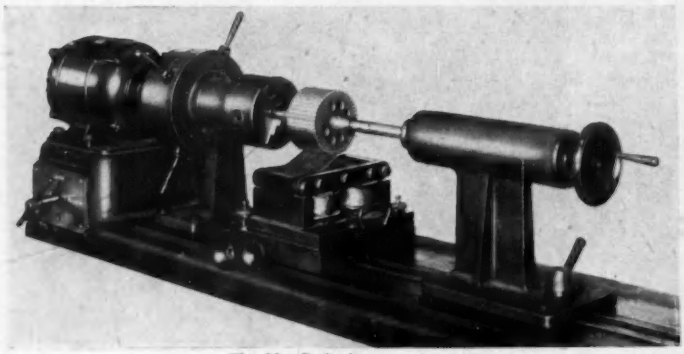


Fig. 29. Cathode ray rotor tester.

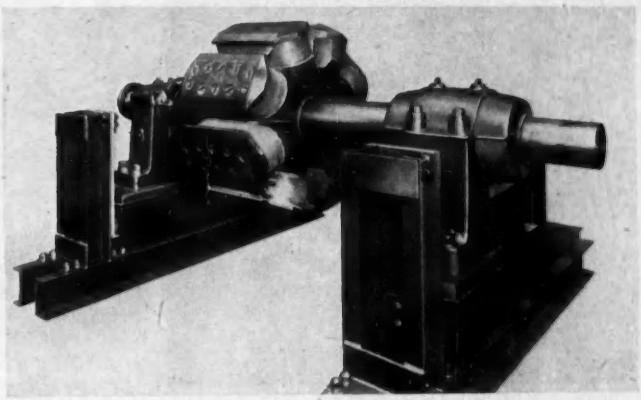


Fig. 30. Prototype of a large dynamic balancing machine with 4-ton rotor.

This machine has been installed for regular production use in several G.E.C. factories.

Tropicalisation Chamber.

In view of the great amount of material supplied during the war for use in the tropics, and the continuing demand since the cessation of hostilities for equipment to operate in such climates, special testing facilities have been devised. The tropicalisation plant (fig. 31) comprises a cabinet for testing the insulation of complete machines, or parts of machines, at any temperature from 20 degs. C. to 100 degs. C. and at relative humidities from 0 to 100 per cent. Under such intensive testing, faults which would not become apparent for many months are revealed in a matter of days. Much valuable data as regards design and manufacture have been gathered in this way.

Impregnation Plant.

The manufacture of capacitors for power factor impro-

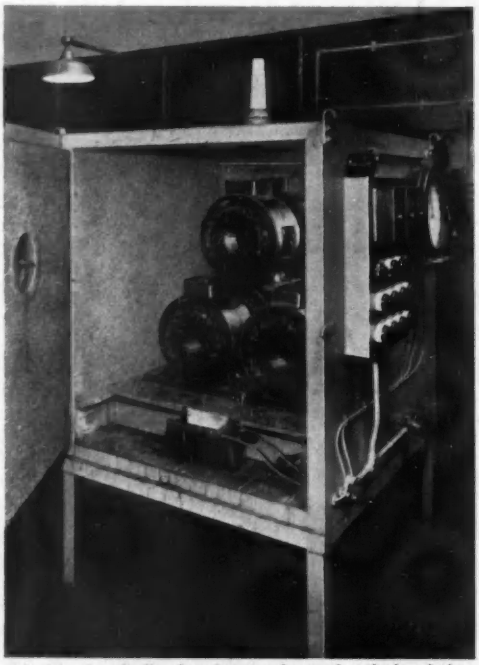


Fig. 31. Tropicalisation chamber for testing the insulation of machines under varying conditions of temperature and humidity.

vement demands very exacting standards of processing as regards vacuum drying and oil impregnation. These requirements arise from considerations of economy no less than from technical reasons since the ratio of kVA to weight must be large and the resistance to high voltage stress fully maintained. The latter requirement entails efficient removal of gas and moisture from dielectric and impregnant. To this end, a new experimental plant has been built which enables the impregnation of capacitors to be carried out under conditions of extremely low pressure both as regards the vacuum drying of dielectrics and vacuum treatment of the impregnants (fig. 32). The information and experience thus gained is being constantly applied to the actual processes of manufacture.

PROTECTIVE GEAR.

Discriminative Feeder Protection.

The simplicity and low initial cost of overcurrent protection has rendered it the most popular type in modern networks for all but the largest feeders. Its disadvantage is lack of discrimination which may shut down healthy parts of a network unnecessarily. To obviate this, time delay devices have long been employed. The inherent limitations of such devices have been overcome by the recently developed Habgood system. This system uses any of the well-established time delayed overcurrent and/or earth leakage schemes and by the installation of relatively simple apparatus at each substation and, as shown in fig. 34, a pair of pilot wires between them, achieves a high degree of discrimination which ensures that only the faulty section is shut down. The additional apparatus comprises high speed relays with slightly lower settings than the normal protective relays and connected in series with them. The operation of any one of the high speed relays actuates a lockout relay in the next substation nearer the power supply. Three discriminating relays and one lockout relay are frequently mounted in one case (fig. 33). The application of this system to a typical radial feeder from a power station *P* supplying a number of substations *A*, *B*, etc., is shown in fig. 34. If a fault occurs at *Z* an overcurrent and/or earth leakage current will flow from station *P* through substation *A*, but not through substation *B*. The discriminating relay at *A* will operate and energise the locking relay at *P*. The

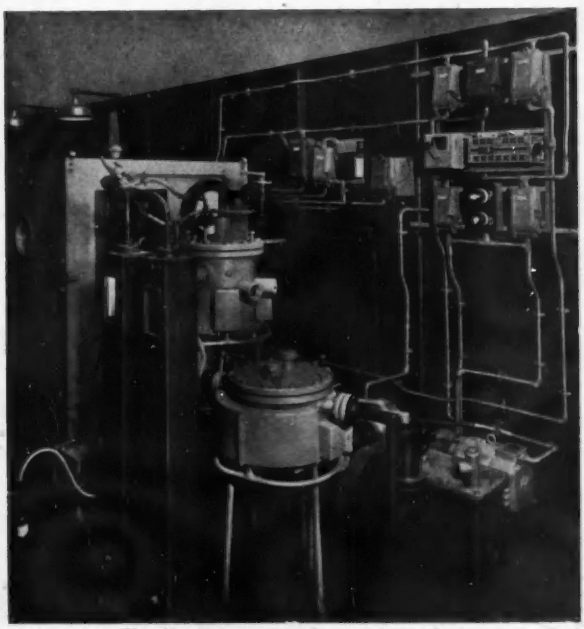


Fig. 32. Experimental impregnation plant.

discriminating relay at *B* will not operate, and the overcurrent and earth leakage relays at *A* will be free to carry out their normal function of tripping the circuit breaker at *A*, while the circuit breaker at *P* will be prevented from tripping.

The same principle is applicable to ring main feeders, where power can be fed in either direction, by the introduction of an auto-reclosed key circuit breaker at one point in the ring. Upon the occurrence of a fault, the

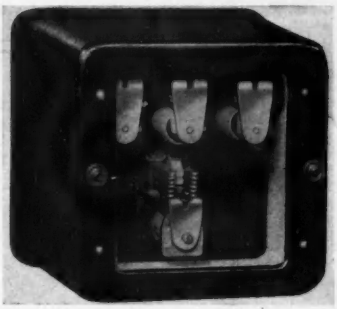


Fig. 33. Discriminating and pilot relays. Habgood protection.

key circuit breaker opens, thus temporarily dividing the ring into two radial feeders. The protective gear now operates as previously described to isolate the faulty section of the network. This is followed by the reclosing of the key circuit breaker and the restoration of the supply to the remainder of the ring.

Overcurrent Relay.

A new inverse time delay overcurrent relay (type *B*) has been introduced which complies fully with the requirements of the appropriate British Standard Specification. The relay, which is manufactured at the Company's Chamberlain & Hookham Works, is

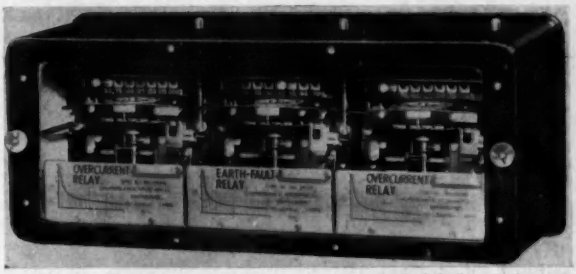


Fig. 35. Inverse time delay overcurrent and earth leakage relay.

an induction instrument with inverse time and definite minimum time characteristics suitable for overcurrent and earth leakage protective schemes. A distinctive feature is the method of utilising a saturable current transformer to supply the upper and lower magnet windings in parallel. The primary of the saturable current transformer is connected to the secondary of the appropriate line current transformer. All available winding space on the relay is thus occupied by useful turns and consequently its volt-ampere consumption is low, about 1·5 VA. Another

Fig. 36. Instantaneous relay, telephone type.

feature of the saturable transformer is its high overcurrent factor preventing undue stress on the relay under such conditions.

The relay can be supplied as an overcurrent or earth leakage element; it has easily adjustable current and time settings and is fitted with a prominent flag indicator interlocked with the disc. The general appearance of the relay is seen in fig. 35.

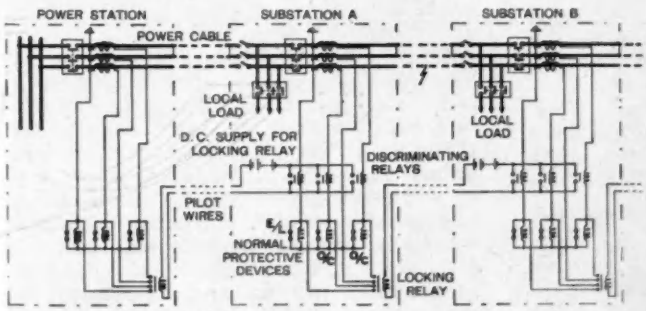


Fig. 34. Discriminative protection applied to a typical radial feeder.

Telephone Type Relays.

Hitherto there has been a certain reluctance to use communications equipment in connection with power supply systems. However, the telephone type relay is now accepted for use with protective gear on account of its reliability, adaptability, small size, low power requirements and high operating speeds. The Telephone Works at Coventry has produced a relay with increased insulation to

withstand a flash test of 2,000 volts between contacts, coil and frame, and capable of handling 2,000 volt-amperes. These relays can be fitted with make and/or break contacts and a hand reset flag indicator. The contacts themselves can be arranged so as to be either hand-resetting or self-resetting. Recent applications of this relay include high speed tripping, inter-tripping and alarm. A flush pattern alarm relay with hand-reset contacts and flag indicator is shown in fig. 36. Projecting or flush pattern cases are available for either front-of-board or internal cubicle mounting.

TELECOMMUNICATIONS.

Radio Communication.

Most of the development in radio communication during the past year has been in the V.H.F. band, 30 to 300 Mc/s. Considerable progress has also been made in such fields as broadcasting, police radio communication, and railway traffic control.

V.H.F. Point to Point Communication.

Communication at radio frequencies greater than 30 Mc/s. is normally restricted to optical range. The G.E.C. frequency modulated equipment, which operates in the 30—150 Mc/s. band gives a service area, from a 100 ft. mast to a mobile car, of 20 to 30 miles radius.

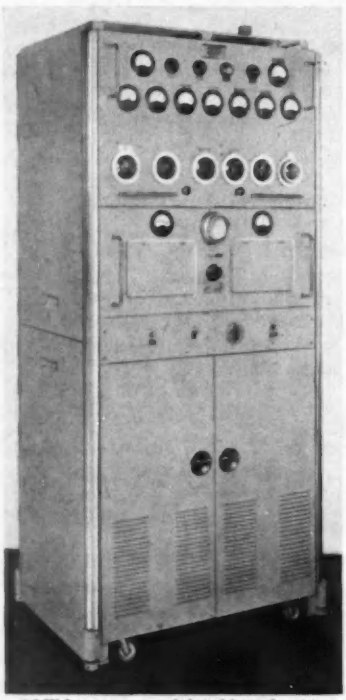


Fig. 37.—1 kW frequency modulated broadcast transmitter.

It is desirable in certain circumstances to increase this radius without increasing the equipment which has to be carried in the car. This involves the use of two transmitters operating on the same frequency and carrying the same modulation. An interesting series of experiments has been carried out to investigate this problem. Clearly, the two transmitters must operate on exactly the same frequency so that undesirable beats may be avoided in the region where their two coverage areas overlap. Of the several possible methods by which this might have been effected that described below was considered to be technically the most promising.

At the main station two transmitters were used. The normal transmitter, which gives a circular coverage, was, for the purpose of these experiments, operated on a frequency of 100 Mc/s. A second transmitter at the main station was arranged to carry the same modulation as the normal transmitter at a carrier frequency which, by using frequency multiplying circuits, was held at exactly $2\frac{1}{2}$ times that of the normal transmitter, that is, 250 Mc/s. The second transmitter fed an aerial beamed on to a remote station outside the service area of the main transmitter. At this remote station, the signal was received, divided in frequency by $2\frac{1}{2}$ by means of a regenerative divider, amplified and retransmitted from an aerial with circular coverage. Extensive tests with this arrangement showed that it was possible to discover small areas where the interaction of the two stations caused some distortion and increase of background noise, but that the effect was not sufficient to reduce the combined service areas of the two stations.

Work has been carried on in conjunction with the railway authorities on the application of V.H.F. to communication between the guard and driver of a train, between a train and signal boxes alongside the track, and between breakdown gangs and signal boxes. The effect on propagation of deep cuttings and tunnels, including long tunnels with 'S' bends, has been investigated, as also has the effect of the high audio noise level in certain engines. An interesting application of V.H.F. to railway working is the fitting of the standard G.E.C. frequency modulated equipment both to the pilot train and the Royal train for Their Majesties' tour of South Africa. The two trains are thus able to maintain constant telephonic communication.

Tests made by the Home Office using G.E.C. amplitude modulated equipment have determined the best type of noise suppressor and the best audio response characteristic for use in police and similar services. As a result, modifications have been made to all amplitude and frequency modulated receivers.

A new control panel for mobile units is an interesting example of advance in design; although it contains a loudspeaker it is small enough to be fitted into the dashboard of a car. A second example is a unit incorporating a 100 watt transmitter and receiver, of attractive and compact design, in which all components are easily accessible. It is particularly suitable for tropical use as it is ventilated by a fan and has dust filters on the air inlets and outlets.

V.H.F. Frequency Modulated Broadcast Transmitters.

The quality of programmes possible from V.H.F. broadcasting is high, for, on account of the much wider frequency band available, the high audio frequencies need not be restricted as is the case in broadcasting at lower frequencies. This advantage is enhanced by the use of frequency modulation, since the receiver is not affected by electrical interference and gives a very quiet background.

A complete F.M. broadcast transmitter, having an output of 1 kW has been designed, and one of these has been supplied to All India Radio (fig. 37). It incorporates the results of experience gained in the design of transmitters for point to point services and is fully monitored and self-checking in all respects; the copper anode output valves and

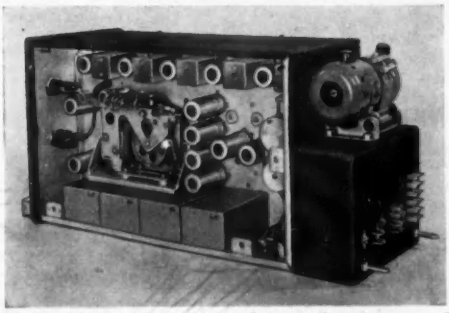


Fig. 38.—Glide-path equipment for assisting the approach and landing of aircraft.

the high tension rectifiers and transformers are cooled with filtered air, and the separate stages can easily be pulled out for servicing. Two amplifiers and their power supplies, similar to the output stages of the above transmitter, have been supplied to the B.B.C.

Aircraft Radio.

A glide path and localiser equipment has been designed for use during the final approach and landing of aircraft. The glide path receiver, which is shown in fig. 38, indicates to the pilot his position above or below a path defined by two overlapping radio beams from a ground station. The localiser receiver gives the pilot left-right bearings either on a landing beam or on separate beacons used to define the path between airports.

Non-contact Circuits for Wide Range Tuning.

An important new technique has been developed for the design of tunable circuit

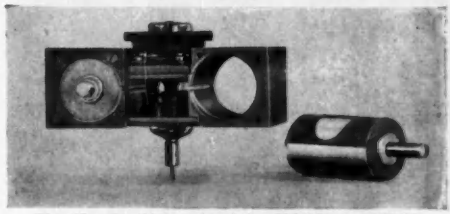


Fig. 39.—Oscillator circuit for 500 Mc. to 1000 Mc. with one rotor removed.

elements to cover a wide range of frequencies at a high frequency. The circuit is shown in fig. 39, connected as the tunable element between the grid and anode of a DET 22 triode. To increase the maximum frequency and the frequency range, the circuit is built in two identical halves which are connected in parallel. Tuning is accomplished by means of two ganged rotors which can be rotated in the cylindrical cavities which form the inductive loops of the tuned circuit. In fig. 39, one of the rotors is shown removed so that the slot which forms the capacitance of the tuned circuit can be seen. This illustration also shows the shape of a conducting silver layer which is fired on to the surface of the solid ceramic rotor. The main function of this silver layer is to provide a capacitative path in parallel with the capacitance of the slot, and it is so shaped that the relationship between frequency and angular rotation is linear.

Circuits of this type eliminate from the tuned circuit the use of rubbing metallic contacts. They also enable units to be designed which are more compact than the co-axial line resonators hitherto employed.

Television.

Since the end of the war a table model television receiver has been developed which is suitable also for long, medium and short wave broadcast reception, fig. 40. The

receiver is housed in a cabinet 25 ins. wide by 16 ins. high by 14½ ins. deep and is thus not much larger than a table radio set. The only controls necessary for normal operation of the set on television are sound volume, picture brightness and picture focus. These, together with the radio tuning control, are situated on the front panel. In addition,

Fig. 40.—New table model television receiver.

selection of the facilities of television, medium, long, and short wave broadcast is obtained by push button control.

A magnetically focused and deflected cathode ray tube of 9 ins. diameter is used to give a picture of about 8 ins. × 6⅜ ins. A considerable improvement over pre-war designs has been achieved by the use of cathode ray tubes with flat screens which are referred to later. The video channel uses miniature high slope H.F. pentodes (Z77) for R.F. and I.F. amplification and is designed to make full use of the maximum frequency band transmitted by the London station, namely 2·7 Mc/s sideband. Both sound and vision circuits are provided with limiters to reduce the effect of ignition interference from cars in localities with poor reception. The overall sensitivity is sufficient for operation over the whole of the service area of the London station, and, in favourable localities, very considerably beyond it.

Public Address Systems.

A new public address system for use in warships has been developed in conjunction with the Admiralty and is suitable for ships of all classes. This flexibility is provided by the use of two amplifiers; for small installations a 60 watt amplifier is used alone, in larger installations a further amplifier of 300 watts output is added. Other units provided are an alarm unit which produces various alarm notes, an automatic gain control pre-amplifier which has a constant output for a wide range of inputs, and a control unit which enables various combinations of loudspeakers to be selected at will and determines the priority to be given to different services. The equipment has mountings specially designed to protect the apparatus from the very severe shocks likely to be met with in naval service.

A new ribbon microphone and a multi-beam loudspeaker have also been developed for high grade equipments for use in the entertainment field. When used together the combination gives a high level of speech assistance with the minimum tendency to ring round.

An interesting development is an individual loudspeaker intended for use in passenger aircraft. The head rest of each seat has a loudspeaker built into it so that passengers may listen to broadcast programmes without the inconvenience of wearing headphones, and also without annoying other passengers.

Telephone and Kindred Equipment.

Carrier Telephone Sets.

Many telephone administrations are now bringing their equipment up to date to meet increased traffic, and the need has arisen to provide additional speech channels over new and existing telephone circuits, particularly on the long trunk routes. The G.E.C. single-channel and three-channel carrier sets have been re-designed and are now more compact, more flexible and easier to install. A.C. mains operation has replaced storage battery power supplies. Although the size has been reduced, the oscillator and filter stability has been improved by the use of special coils of very low temperature coefficient trimmed by capacitors of opposite temperature coefficient; lining up and maintenance have thereby been simplified. Particular attention has been given to the choice of materials and finishes to make the equipment suitable for service in the tropics.

As an example of the possibilities of carrier equipment, the services provided over an Oil Company's open wire line may be quoted. A voice frequency telephone circuit and a telegraph service (phantom circuit, earth return), occupy the frequency band 300 to 2,700 c/s. A four-channel voice frequency telegraph service, occupying the frequency band from 3,900 to 7,000 c/s provides three teleprinter channels and automatic telephone dialling. Finally, a three-channel carrier

telephone system operating on the frequency band from 7,000 to 30,400 c/s provides three telephone services.

Telephone Repeaters.

A new voice frequency telephone repeater in which storage battery supplies are replaced by A.C. mains has been developed for long telephone circuits. The maximum gain is 20 or 27 db., depending on whether it is used with two-wire or four-wire circuits, with adjustment over a 20 db. range. Negative feedback in the amplifier circuit gives a gain characteristic which is flat within 1 db. from 300 to 5,000 c/s. The characteristic impedance is adjustable to match lines of 300, 600 and 1,200 ohms impedance, so that no matching transformer is normally required.

Supervisory Control.

Three major advances made in supervisory control gear are : increase in signalling speeds, reduction in size of control panels, and the development of the "Six Pulse" system.

In a new control equipment supplied to the London Passenger Transport Board the signalling circuits have been so designed that

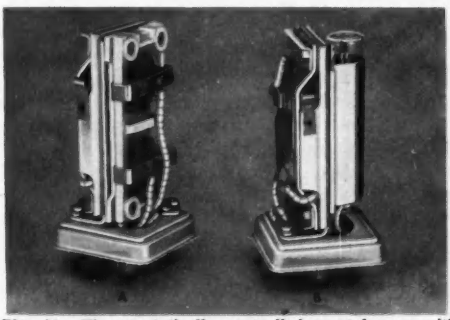


Fig. 41.—Thermostatically controlled crystal oven with cover removed.
(a). Non-vacuum type mounting with two crystal units.
(b). Vacuum mounted bar type.

any one of seventy circuit breakers can be selected in one second. In another installation adopted by the Central Electricity Board, for use at Meaford, the "Six Pulse" system has been used. In this system each meter indication is transmitted as a code of six impulses and the accuracy of repetition is within 2 per cent.

An installation for the remote control of irrigation from a 50 mile canal in New Zealand is notable for its simplicity. Five sluice gates can be opened or closed progressively and the exact position of each gate is indicated at the control station. The signalling system is based on the selective ringing telephone system supplied to railway companies for train control. A pair of pilot wires runs the whole length of the canal, and the control apparatus for each sluice gate comprises a single selector and a few relays.

Relays.

A recent development is the multi-contact miniature relay, which is extremely compact and robust and is intended for use in portable equipment and other services where weight and space are at a premium. The contact material is platinum for ordinary applications and silver-nickel Elkonite where a high current breaking capacity is required. The relay is normally sealed in a can and is suitable for service in any climate.

Quartz Oscillator Crystals.

During the past year the new technique of metallising and soldering quartz plates to fine wire has been extended, and a considerable advance has been made in the method of assembly of the complete unit. A comprehensive range of units has now been developed covering frequencies from 4 kc/s to about 15 Mc/s. A number of types are mounted in evacuated glass envelopes, the higher frequency types in the miniature 7-pin (B7G) envelope and the lower frequency types in larger envelopes mounted on octal bases.

A new range of holders has been developed in which polythene has superseded bakelite. These holders have very low losses and are effectively sealed against moisture.

In order to meet the very high frequency stability requirements of V.H.F. radio equipment a small plug-in thermostat unit which accommodates both types of crystal has been developed. Two units are shown in fig. 41. For normal purposes the thermostat heater is rated at 12 volts, 18 watts, and is suitable for ambient temperatures from 0 degs. C. to 60 degs. C. Higher wattage heaters have been designed to cater for lower temperatures. With the aid of the thermostat a frequency stability of better than 10 parts in a million can be attained.

In cutting plates from natural crystalline quartz there is considerable wastage of material because of the presence of electrically twinned crystals. It has been found that, by applying a mechanical strain to the twinned crystal while it is being taken through a heat cycle it is possible to make such material into single perfect crystals.

Another important development is that of producing synthetic crystalline quartz. Hitherto, only very small crystals of no com-

mercial value had been produced, but recently synthetic crystal plates have been made of sufficient size to permit normal oscillator crystals to be cut from them.

VALVES.

Transmitting Types.

With the return of peacetime conditions, the emphasis in development is on the continuous wave performance of transmitting valves. This raises technical problems of a different nature from those met in the war, when the demands of Radar called for high output under pulse conditions. Several new transmitting types are being developed to extend the range of valves available for use as oscillators or amplifiers at very high frequencies, and some are already available as samples for test in equipment. Although, so far, no commercial supplies have been planned, some of the types will undoubtedly figure in future manufacturing programmes.

The E1769 is a small disc seal triode with an anode dissipation of 20 watts, filling the gap between the DET 22 (10 watts), and the E1457 (75 watts). The new valve operates as an oscillator or as an amplifier at frequencies up to 1,500 Mc/s.

In the direction of higher powers, the E1860 is an air-cooled triode having an indirectly heated oxide coated cathode and an anode dissipation of 1,500 watts. It operates with good efficiency at frequencies up to 200 Mc/s.

A new water-cooled valve, CAT21, has been developed to give powers of the order of 20 kW at frequencies up to 50 Mc/s and slightly less at 100 Mc/s. By the use of new constructional techniques it has been possible greatly to reduce the size of the new valve

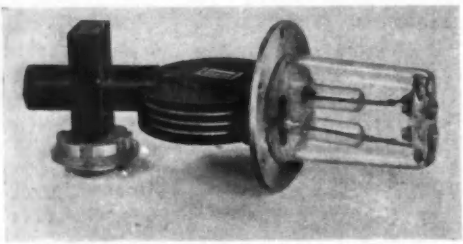


Fig. 42.—3.2 cm. magnetron for marine Radar.

compared with earlier types of similar rating In spite of its small size, the anode can handle a dissipation of 20 kW and the pure tungsten filament provides 25 amperes emission at 90 per cent saturation. The maximum D.C. anode voltage is 10 kV. This valve is also being developed in an air-cooled form (E1845) with an anode dissipation rating of 10 kW. It is hoped to achieve this high rating by the use of a new type of cooler which, besides being considerably lighter, is more efficient than earlier types and operates at a lower air pressure.

Both these valves are of robust construction and are suitable for use in industrial equipment. In addition, because of their high emission and low interelectrode capacitances, they operate with high efficiency as wide band amplifiers, such as are required for television broadcasting.

A transmitting magnetron developed for use in Radar equipment for the Merchant Navy operates at a wavelength of about 3·2 cms. and gives a pulse power output of

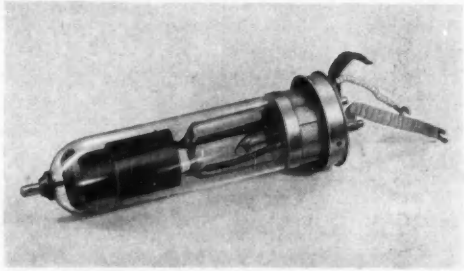


Fig. 43.—Grid-controlled mercury vapour rectifier, E1850.

45 kW with an efficiency of 30 per cent. This valve is seen in fig. 42 which illustrates particularly the waveguide output coupling connection and the protected cathode supports.

Power supplies for the high power transmitting valves necessitated development of several new rectifiers. One of these, shown in fig. 43, is the E1850, a mercury vapour filled, grid-controlled rectifier for continuous working. A set of these valves in a three-phase full wave rectifier circuit will give a maximum output of 10 kV and 6 amps., the 2·5 volt filament consuming 100 watts. It is a positive control valve suitable for use in the well-known rectifier circuits in which alteration of the phase of the grid excitation is used to control the output. The valve, which is approximately 300 mm. long and 96 mm. in diameter, is supplied capped and surrounded by a Tufnol tube so that a thermostatically controlled warm air blast may be used to provide a constant condensation temperature. The illustration shows the valve capped but with the Tufnol tube removed to show more clearly the electrode structure.

Receiving Types.

In the field of receiving valves one of the most important recent developments has been

a miniature triode, E1714, designed for high frequency, low noise level amplifiers. This valve incorporates planar electrodes as distinct from the more conventional concentric cylindrical arrangement, and some of the techniques employed in the u.h.f. triodes developed

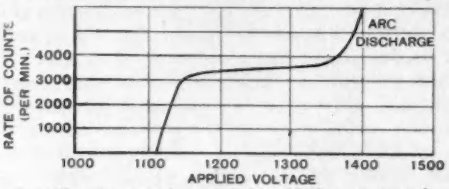


Fig. 44.—Characteristic of Geiger-Müller counter tube.

during the war, which required very small interelectrode spacings, have been adopted. In this way high mutual conductances coupled with low interelectrode capacitances have been achieved, the valve having a mutual conductance of 7·8 mA/volt at 10 mA anode current with grid-cathode and grid-anode capacitances of 1·8 and 0·9 micro-micro-farads respectively. The valve is still in the experimental sample stage and tests have shown that with this type as the first stage of a 45 Mc/s amplifier a noise factor of 2·8 db. can be obtained, with a band width of 12 Mc/s.

Detector and Mixer Crystals.

Experience gained during the war has indicated that the fewer controls provided on an equipment, the more likely it is to be adjusted to its optimum performance in the hands of an unskilled operator. The trend has therefore been to design "pre-matched" mixer units incorporating crystal valves, so that no adjustment is available after manufacture. This has necessitated working to very close tolerances in the manufacture of crystals.

A considerable amount of attention has been paid to the behaviour of crystal valves at temperatures approaching 100 degs. C. and humidities up to 100 per cent. To meet such conditions the "cartridge" has now been made vacuum tight and the wax previously used has been omitted.

In parallel with the work on silicon crystals a comprehensive study is being made of the performance of units incorporating germanium. This material is similar in many respects to silicon and very promising results have been obtained with it both as a mixer and as a detector.

Gas Discharge Devices.

In gas-filled transmit-receive switches for Radar systems employing a common aerial for transmission and reception, the gas fillings must be chosen to give rapid deionisation when the exciting voltage is removed. Water vapour has been widely employed but normally gives too short a life for peacetime applications such as Merchant Navy Radar where continuous searching is necessary. Considerable advances have been made in understanding the nature of the disappearance of the water vapour filling during life, and it is expected that a new method of saturating the interior walls of the valve will result in a great improvement in performance.

Geiger-Müller Counter Tubes.

With the increasing interest in radioactive materials a growing demand has arisen for devices which detect and measure radiation from radioactive substances. One of the most important of these is the Geiger-Müller counter tube which consists essentially of a gas-filled diode, the anode of which is a thin axial wire and the cathode a surrounding metal cylinder. When a voltage of rather more than 1 kV is applied between the electrodes, any ionising particle such as a β particle which penetrates to the space inside, causes a sheath of ions to build up around the central electrode. These are collected and give a

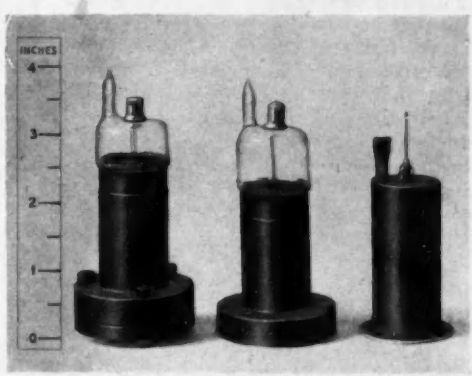


Fig. 45.—Various types of Geiger-Müller counter tubes.

voltage impulse of the order of one volt which can be amplified and registered on a suitable counting device. The number of such impulses recorded from a tube receiving a constant amount of radiation is a function of the applied voltage, as shown in fig. 44. Over a range of about 200 volts, known as the "plateau," this number is sensibly constant and at a higher voltage the tube goes into a continuous arc discharge.

This device has of course been known for

some time but it has always proved difficult to make other than on a very limited scale. Various experimental counter tubes have been developed (fig. 45), which can be produced in considerably larger numbers, and with a greater reliability than has hitherto been possible. One of the most important

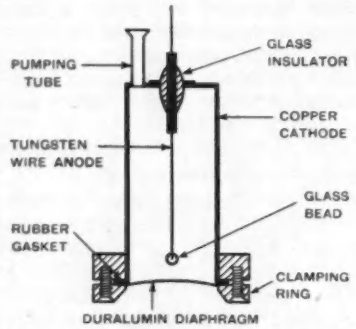


Fig. 46.—Section through Geiger-Müller counter tube.

applications of these counters is the detection of fast moving β particles from radioactive materials, and for this purpose a thin window of copper foil covers the end of the tube. For slower β particles, a type of tube with a duralumin foil window, one inch in diameter and less than 0·001 inch thick, has been used and is shown in cross-section in fig. 46. Some idea of the sensitivity of these counters can be gained from the fact that the small amount of radioactive material on a luminous watch dial, held about one inch from the window, will cause impulses to be registered at a rate of several thousand per minute.

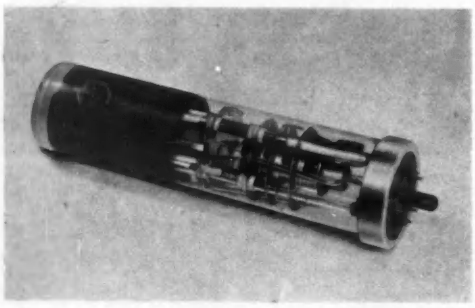


Fig. 47.—Cathode ray tube mounted on pressed glass base; diameter of tube 1½ inches.

Cathode Ray Tubes.

During the past year the technical advances in cathode ray tubes have been mainly along the lines of improvements in manufacturing techniques. The use of the pressed base for tubes in which overall length is of importance has become established in pre-production and is illustrated in fig. 47, which shows a 1½ inch tube developed for Miniature Gee, a miniature version of the famous war-time navigational aid. The employment of pressed screen ends, enabling flatter screens to be produced than is economically possible by the traditional methods of glass-blowing, has become an established technique. A range of pressed ends is shown in fig. 48.

The year 1946 has seen the return to production of television apparatus and a 9 in. tube, 6501, has been developed with a pressed screen of 1,000 mm. radius of curvature. Improved techniques of application of the fluorescent powder have resulted in screen efficiencies 50 per cent higher than before the war.

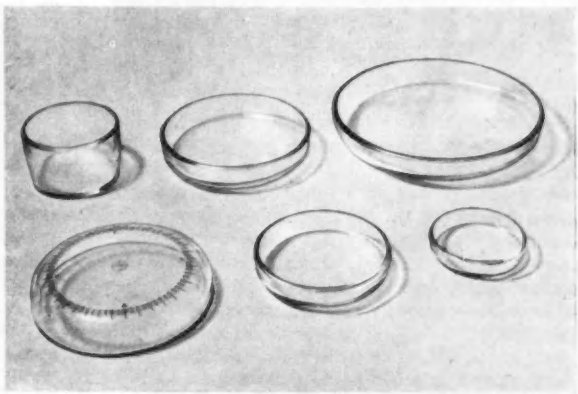


Fig. 48.—Pressed ends for cathode ray tubes.

Attention has been directed towards oscillograph tubes for high speed recording and comparatively simple modifications to the standard tube have resulted in a very satisfactory experimental design illustrated in fig. 49. The leads to the work plates are brought out very close to the final accelerator and the time base deflectors are connected to side arms on opposite sides of the bulb. Fairly complete interplate screening results in a feedback capacitance of 0·2 micro-micro-farad from one X plate to one Y plate with all other electrodes earthed. Working at an accelerator voltage of 10 kV and with the comparatively low lens aperture of $f3{\cdot}5$, time intervals of 10^{-8} secs.

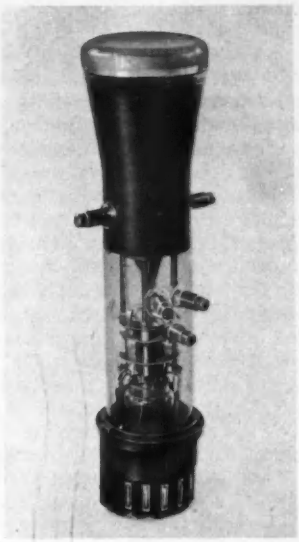


Fig. 49.—High speed recording cathode ray tube.

can be resolved. This tube has a pressed screen of 3½ ins. diameter.

MEASURING INSTRUMENTS.

The period of specialisation caused by the war has ended, and effort is again being directed to more general requirements. For example, the whole range of switchboard instruments is being redesigned. In the field of radio, the attention naturally demanded during the war by instruments required for Radar has now been largely transferred to those needed for communications and general measurement. In this process of readjustment to the needs of peace, much experience gained during the war is now being put to more general use.

TRANSIENT TEST SET.

The field of application of transient response testing is considerable. In such systems as television and Radar, which are built to transmit transient signals, transient testing is clearly required. In others, although the need for transient tests is less evident, their adoption may simplify testing procedure. A simple example is the matching of cables, where any mismatch or fault will produce a reflection which appears on the display unit as an echo of the original transient signal. Furthermore, the echo is shifted in time by an amount which is directly related to the position of the mismatch. Another application, less evident but leading to very useful results, is the study of the stability of feedback amplifiers. A transient test shows their degree of stability, and the frequency at which oscillations may occur.

Two types of transient test set have been developed; both determine the behaviour of a network by showing visually on a cathode ray tube its response to a short impulse. In one, this impulse is about 18 volts in an impedance of 17 ohms, lasting for 0·01 microsecond; in the other, the impulse may be varied in duration continuously from 0·1 to 50·0 microseconds. Fig. 50(a) shows an oscillogram of a test impulse which is approximately 0·01 microsecond wide at half height. Figs. 50 (b) (i) and (ii) show the output from a single stage amplifier when such an impulse is applied to its input. The output circuit is a simple band pass filter with resistance terminations across both primary and secondary circuits in (b) (i), and across the secondary only in (b) (ii).

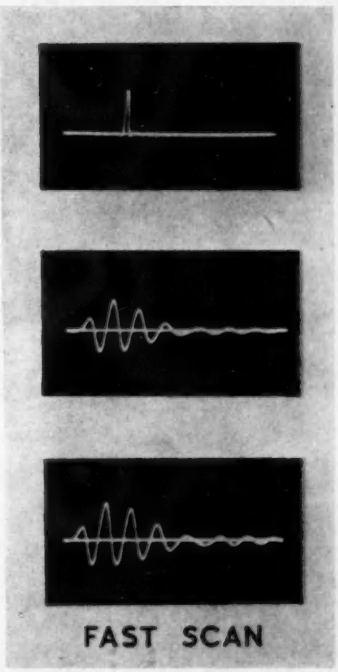


Fig. 50.—(a) Oscillogram of test impulse, 0.01 microsecond wide at half height.

(b) Response of single-stage amplifier having a simple band pass filter as output circuit:

(i) Resistance terminations across primary and secondary circuits.

(ii) Resistance terminations across secondary circuit only.

Current Measurement.

(a) Copper Oxide Rectifiers.

New techniques have been evolved for the manufacture of copper oxide rectifiers for use in instruments. Plates coated with oxide are cemented together by an electrically conducting silver adhesive; the assembly is then sealed in a polythene case by injection moulding. This technique gives a considerably smaller rectifier of great stability. For use at high frequencies, small plates have been mounted in ceramic tubes which are then hermetically sealed in polythene. Copper oxide rectifiers are available for currents from 100 micro-amperes to 1 ampere.

(b) Current Transformers for High Frequencies.

An air-cooled toroidal transformer has been employed successfully for the measurement of currents up to 30 amps. at frequencies up to 50 Mc/s. The toroidal secondary winding consists of a few turns of copper strip wound on a split copper former which acts as a shield to eliminate variations due to the leakage field between the turns of the secondary. The primary is a single conductor linking the toroid and is usually part of the tank coil of a power oscillator.

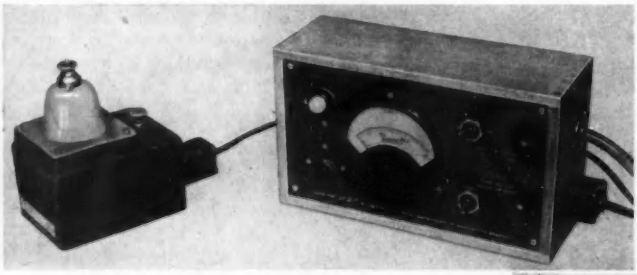


Fig. 51.—*(above)* **Indicator unit and 1 kV head unit for high voltage valve voltmeter.**
(right) **10 kV head for high voltage valve voltmeter.**

Valve Voltmeters for High Voltages.

The range of valve voltmeters has been extended to cover the voltages which are used in industry in high frequency oscillators, notably those for high frequency heating or in high power transmitters. A normal type of diode peak voltmeter is employed in conjunction with capacitance potential dividers. Voltages up to 10,000 can be measured at frequencies up to 50 Mc/s. Two different head units are available giving maximum voltages of 1,000 and 10,000. These two units, together with the indicator unit, are shown in fig. 51.

Impedance Measurements.

In the conventional type of Q-meter a calibrated resistance is used, and the satisfactory performance of the instrument over a wide range is dependent upon the calibration remaining unchanged. This limitation is the main source of error in Q-meters at frequencies above 10 Mc/s. Of the three circuit components, resistor, capacitor, and inductor, the capacitor generally retains its low frequency calibration to much higher frequencies than do the other two. It is therefore clearly desirable to replace the calibrated resistor by a capacitor.

Because of these considerations a new method of measuring Q involving capacitors only has been developed. It may be described with reference to fig. 52. A low impedance generator, e, feeds two capacitors in series, C_1 and C_2; C_2 is much greater than C_1. The component L, whose Q is required, is connected in parallel with C_2 which is then adjusted to bring the coil to resonance, as indicated by a voltmeter across the resonant circuit. It can easily be shown that, provided

the ratio of C_1 to C_2 remains constant, the voltmeter gives an indication proportional to the Q which it is desired to measure. The Q meter thus consists of an oscillator of constant output, two capacitors carefully ganged to maintain constant ratio, and a voltmeter which is calibrated directly in Q values. It will be noticed that the calibration depends only on the values of the two capacitors. The instrument, which is illustrated in fig. 53, is being produced in two models covering 25 kcs to 50 Mc/s and capacitances up to 500 micro-micro-farads in the one case, and 15 to 150 Mc/s and capacitances up to 100 micro-micro-farads in the other. In both cases Q values can be measured up to 500 in two ranges, the scales being approximately linear.

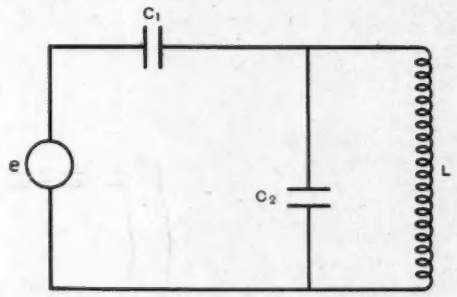


Fig. 52.—Basic circuit diagram of the new Q-meter.

LAMPS AND ILLUMINATION.

General.

During the past year much attention has been given to the problems of increasing the efficiency of fluorescent lamps. Considerable advances have been made in high pressure mercury vapour, high intensity arc, and tungsten filament lamps. Problems connected with cinema studio lighting which could not be considered during wartime are now being solved. Lighting for civil aviation, which differs entirely from either pre-war or wartime lighting, is receiving a good deal of attention, particularly in dealing with bad weather conditions.

These, and other studies in the production and application of light, are described in the following sections, but in so short a survey only some of the successful experiments can be covered. It is also impossible to discuss the many ancillary problems which arise. For example, lighting as it is known to-day could not exist without glass, and research into its properties is of vital importance. One example of the research which is being carried out in this field is the production of special refractory materials for lining the tanks in which glass is melted. A small pilot plant is now in operation, and the first blocks produced in it have given satisfactory service.

Fluorescent Lamps.

The design of fittings for fluorescent lamps will be made easier by the introduction of "long" chokes and capacitors which can be mounted in a narrow channel associated with the fitting. These chokes are of the tapless type and are made in three ranges to cover the usual supply voltages.

A canister type starter, which incorporates a switch slightly smaller than the original 80 watt switch, and includes an 0·02 mfd. condenser for radio interference suppression, has been introduced. Although the canister is fitted with a four contact base to make it interchangeable with the thermal type of switch, only two contacts are used, the other two being short-circuited. The switch holder also contains a device for short-circuiting the heater contacts when the starter is removed. Thus, once the lamp has been started, it will continue to function even if the switch is removed. In the 40 watt starter, the initial ionisation necessary for dark starting is now achieved by painting an aluminium film across the top of the pinch and breaking this down electrically after pumping. The high field strength between the separate aluminium particles so produced is sufficient to cause the initial ionisation necessary for the starting of the glow discharge.

Fig. 53.—The new Q-meter

Low voltage starters housed in four-contact canisters have also been designed to operate the 20 watt lamp. These incorporate barium activated electrodes with a helium-argon filling to enable them to operate on 110 volt circuits.

Fig. 54.—Osram fluorescent lamps installed in an experimental car on the District Railway.

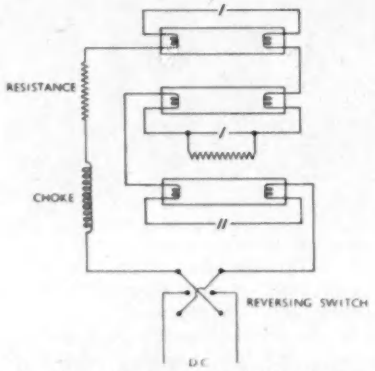


Fig. 55. Circuit used in District Railway experimental car for operating 20 watt fluorescent lamps on a 600 volt D.C. supply.

Starters for D.C. operation are also under development. In these, a symmetrical electrode arrangement is necessary since the mains voltage must frequently be reversed to avoid electrophoresis of the lamp.

One of the most important uses for fluorescent lamps operating on D.C. is for lighting transport vehicles. The general problem is one of the most difficult which faces the engineer, on account of such conditions as vibration, lack of space, and often the limited power supply available. The first major obstacle to be surmounted was the provision of an electrical supply of at least 65 volts. This could be done by means of a motor-generator booster, a motor alternator, or a vibrator unit. The last gives a high overall efficiency, but has the objection that output and life per vibrator are low. The booster, besides having a low efficiency, leads to a reduced lamp life. The motor alternator also has a low efficiency but gives a normal lamp life. On trolley buses and trains where D.C. voltages above 60 volts are already available, straightforward D.C. operation may be cheaper to install and no less efficient, but wide voltage variations may be met. On alternating circuits at frequencies above 250 cycles per sec., a semi-resonant circuit can be used, which provides automatic starting without the use of a starter switch and, because of the high frequency, eliminates stroboscopic flicker.

An experimental car was put into service on the District Railway in London in October, 1944. In this car, 2 ft. × 1½ in. 20 watt lamps were used, mounted as shown in fig. 54, and operating three in series from the nominally 600 volt D.C. traction supplies. The circuit is shown in fig. 55. As the D.C. running voltage per lamp is about 70 volts, the operation of three lamps only in series is very wasteful on the 600 volt circuit, but if four lamps are used the available voltage per lamp is barely

sufficient for starting, should the track voltage fall to 450, as may occur in practice.

By March, 1946, this car had run 60,000 miles, and the lamps had been alight over 1,000 hours. The results were excellent. The initial average illumination was 5½ lumens per sq. ft., instead of the 3 lumens per sq. ft. given by the original filament lamps. The colour was much more attractive and there were no harsh shadows or glaring sources. Illumination was steady, though the voltage varied between 630 and 450, and when the supply was interrupted, the lamps restarted instantly.

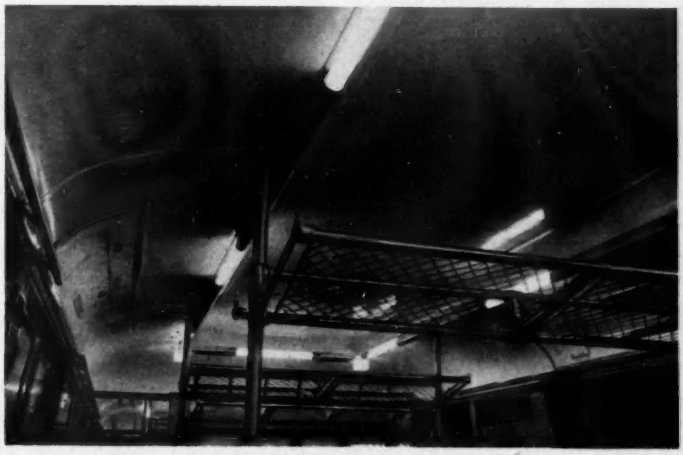


Fig. 56. Layout of lamps in a car on the Metropolitan Railway.

The London Passenger Transport Board next built an experimental car fitted with twenty-four 20 watt 2 ft. × 1½ ins. warm white Osram fluorescent lamps, operated in this case from a 1,200 c/s motor alternator. The layout of the new car is shown in fig. 56, and the circuit in fig. 57. The initial illumination given by this arrangement was 10/15 lumens per sq. ft., at a distance of 2 ft. 6 ins. from the floor.

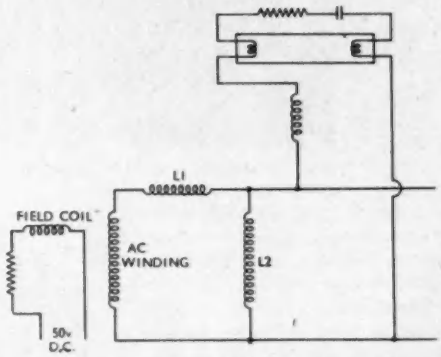


Fig. 57. Lamp and alternator circuit used on the Metropolitan Railway experimental car for 20 watt lamps operating on a 1,200 cycle A.C. supply.

Another interesting application of fluorescent lamps has been to hospital operating theatre fittings. The problem here is to provide high illumination with the light falling on the patient over a wide range of angles (so-called "shadowless" lighting) but, at the same time, to keep the radiant heating low. Owing to the physical dimensions of the fluorescent lamp, it is not possible to concentrate the light into a small circular area. For the lighting of an operating table the narrow strip of 5 ft. length which can be achieved may, however, offer the advantage that, as the whole length of the table is illuminated, there will be less need to move the fitting during an operation. Fig. 58 shows a fitting installed at the Ancoats Hospital, Manchester, in which five 80 watt daylight lamps arranged in an arc in concentrating reflectors, are used to provide an illuminated area, 5 ft. × 1 ft. The shadowless quality of the system is excellent, since the effective source of light is a rectangle 5 ft. × 4 ft., and this is achieved without concentration of heat, so that discomfort to the surgeon is avoided. The illumination is of the order of 400 lumens/sq. ft. when the fitting is mounted at a height of 3 ft. above the table. Four 100 watt tungsten lamps in separate parabolic reflectors housed in the ends of the fitting are sufficient to

provide 150 lumens/sq. ft. of emergency lighting. They are wired to an alternative supply as a safeguard against all possibility of a breakdown. The fitting can be tilted in any direction by an arrangement of ceiling pulleys, but adjustment of height has been found unnecessary because of the comparatively large size of the illuminated area. The fitting is constructed in aluminium, in order to keep its weight to a minimum, and anodised aluminium is used for the reflectors.

Fig. 58. Hospital Operating Theatre fitting using 5 ft. fluorescent lamps.

Industrial uses of fluorescent lighting continue to increase, and equipment for specialised purposes is being developed. A fitting of particular interest is intended for use where excessive moisture, dust, or even a corrosive atmosphere are likely to be met with. Such conditions demand a robust, vapour-proof construction which serves to protect all gear components, wiring connections, etc., from the atmosphere. To ensure that the fitting is vapour-proof, all holes in the end castings are fitted with rubber sealing glands, and the cover plates which give access to the gear are fitted with rubber gaskets.

High voltage fluorescent lamps are now being made which give more than double the light output per foot obtainable from pre-war tubes. The lumen maintenance has been greatly improved, and despite higher losses inevitably associated with cold cathodes, the performance of high voltage tubes throughout their whole life compares well with that of hot cathode lamps. The lamps can be supplied in daylight and warm white colours as well as in a further colour, known as intermediate white, which has proved very acceptable as a general illuminant.

A unit having three parallel tubes, connected in series and operated from the secondary windings of two transformers connected in tandem, has been found particularly useful for stores, where large areas have to be illuminated to a comparatively high and uniform intensity. The end boxes hold the transformers together with condensers to correct the power factor to ·85. The overall consumption is approximately 240 watts, and the average light output over a period of 6,000 burning hours exceeds 5,000 lumens. Fig. 59 shows a typical installation in which these fittings have been employed to provide an average intensity of about 25 lumens per sq. ft.

A new unit using cold cathode tubing has given very satisfactory results in extended colour matching tests. This unit is simpler

than, and gives ten times the efficiency of, the carbon dioxide units which have hitherto been the accepted source for colour matching in many industries.

Tungsten Filament Lamps.

The tungsten filament lamp still holds an important place in lighting practice, for there are many tasks which it is not easy, or even possible, to perform by the use of any other known source. Typical of these applications is the motor car headlamp. It will be remembered that American lamp designers evolved the sealed beam lamp in an effort to improve the performance of headlights. These lamps are of two types. One is an all glass construction in which the filaments are mounted directly on the reflector, which together with the front glass forms a sealed envelope. In the second type, a twin filament bulb is soldered into position in a metal reflector, which is then sealed on to a prismatic front glass. In both cases, the entire unit must be replaced if the filament burns out.

To avoid this wholesale scrapping while retaining the principal advantages of the new method, a pre-focused bulb has been developed by the G.E.C. in conjunction with J. Lucas & Co., Ltd. In these new lamps, the front glass and reflector are assembled as a unit which cannot be separated. The bulb has a notched flange and thus locks into the correct position when inserted in the holder. This maintains the original beam performance when a replacement bulb is fitted so that no focusing device is required. Since the bulb is fitted from the rear of the reflector, it is essential that the aperture through which it is inserted should be kept as small as possible. The bulb is therefore made cylindrical in shape so as to reduce its overall diameter to a minimum.

A range of fittings of various sizes has been produced, and it is intended that they shall also be used as pass lights, giving a flat topped beam for use when driving towards traffic, or in a fog. Twin filament bulbs are also being produced for use in the near side headlight when a passlight cannot be fitted (fig. 60). The pre-focused bulb will allow much more effective dipping than has hitherto been attained with twin filament headlamp bulbs.

Fig. 59. Artificial flower department in a store illuminated by cold cathode self-contained units with intermediate white tubes.

High Pressure Mercury Vapour Lamps.

During the past year considerable progress has been made in the compact source type of high pressure mercury lamp, principally in securing better colour rendering and in the production of lamps of higher wattage. In addition special circuits have been designed to render the lamps easier to operate.

Modification of the colour of the light emitted by a mercury vapour lamp can be achieved by the addition of metals such as cadmium or zinc which, when excited in the discharge, help to fill up the parts of the spectrum which are not covered by the mercury discharge, in particular, the red band. Although this fact has been recognised in principle for many years, efforts to utilise it have, until recently, not met with much success. The major difficulties have been the temperature which must be attained in the lamp to vaporise the cadmium or zinc and the problems involved in controlling the colour. During the past year, experience in the working and use of fused quartz has made possible the fabrication of lamps which can be run at the high temperatures required, and experimental lamps of ratings from 1 kW to 20 kW, with greatly improved colour rendering properties, have been produced. These lamps will have wide applications; for example, they may have many uses in the film industry, both in the projection and taking of colour

films, and their improved colour will no doubt recommend them for street and general purpose lighting. An example of such an experimental lamp is the 2½ kW colour modified H.P.M.V. lamp shown in fig. 61, of interest for general and background lighting on film sets. It

Fig. 60. Twin filament type pre-focus bulb.

possesses several advantages in comparison with existing types of lamps; it is, for instance, completely silent in operation, and can be left running for many hours without attention. Tests conducted on this and higher wattage colour modified compact source lamps, made in conjunction with Messrs. Technicolor, have given very hopeful results.

Experimental work in the Laboratories has shown the possibility of much higher efficiency H.P.M.V. lamps than those at present available. Thus, a luminous efficiency of some 70 lumens/watt now seems within reach; such lamps when fully developed are expected to have many applications. It has also proved possible to design much larger H.P.M.V. lamps, ratings as high as 25 kW having been employed experimentally (fig. 62).

The problem of restarting a recently extinguished H.P.M.V. lamp has now been solved. It has been known for many years that a dangerously high voltage is required to perform this operation. This disadvantage has been overcome by developing a circuit which will produce the voltage required for restriking the lamp but which will limit its duration to a few microseconds. In this way the lamp can be switched on and off at will without endangering the user: a very important consideration with equipment intended for lighting cinema studios.

Fig. 61. Experimental 2.5 kW colour modified compact source lamp.

Cinema Studio Lighting.

Comparatively few people realise the complex organisation of a cinema studio and the severe demands it makes upon the lighting equipment which must be robust, and yet light, for it will often be mounted at a height of more than fifty feet. The fittings must remain cool enough to be handled, the optical system must be both compact and efficient, the source must be silent so that it does not interfere with the recording of the sound track and, for colour film work, it must have a suitable spectral distribution.

It may well be some years before the colour modified compact source lamps mentioned above form the major part of studio lighting equipment as they are still in the experimental stage. Meanwhile, the development of existing types of lamp is continuing; one such is the new design of 150 ampere arc for colour filming. This is a double negative arc, employing one positive carbon and two negative carbons (fig. 63).

Fig. 62. Experimental 25 kW compact source lamp, 17 inches in height.

A study of the noise emitted by various arcs has shown that it increases rapidly as the current through the negative is increased,

so that there is considerably less noise if the desired current is divided between two negatives. The noise also depends to some extent on the angular setting of the negatives relative to the positive, the optimum setting being that shown in fig. 64. Reduction of

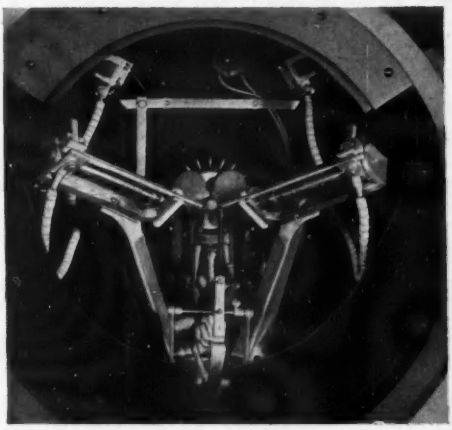


Fig. 63. Experimental double negative 150 ampere arc lamp. The negative carbons and associated feeding mechanism are shown above, while the general appearance of the lamp house is seen to the right.

noise is not the only advantage of the double negative lamp for it is possible to run two lamps in series on the 115 volt studio mains, and so to light a studio set effectively with about half the usual power expenditure. This is possible because the use of two negatives reduces the voltage drop across the arc from 65 volts, the normal value for a single negative arc lamp, to 48 volts. This is the result of shortening the arc gap between the positive and the two negatives, a step necessary to ensure stability. As this does not affect the condition of the positive crater, upon which the useful light output depends, the saving in power does not reduce the light output.

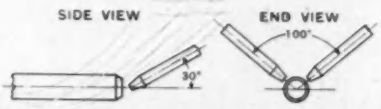


Fig. 64. The position of the two negative carbons in relation to the positive carbon in a 150 ampere double negative arc lamp.

A pair of lamps can be operated either together or singly by using a combined ballast resistance and switch unit, and since all double negative arc lamps are identical and self contained any two can be operated in series. The lamp mechanism and lamp house are largely made from a light alloy material to keep the weight down to a minimum, and the ventilation system permits a high rate of air change so that efficient cooling is obtained. The arc uses standard 8 mm. negative carbons and a special 16 mm. positive.

For black and white photography it is customary to employ tungsten filament lamps, and fig. 65 shows a 2 kW unit using a stepped lens, in which special attention has again been paid to the cooling system. Its double walls, in conjunction with the top and bottom ventilation, make it possible to handle the fitting in comfort, even after long operation. The body is of pressed aluminium, and can easily be dismantled for service and repair (fig. 66). The lenses for this unit, as well as for the 500 watt and 5 kW units, and for the 150 ampere arc unit were designed by the Research Laboratories in conjunction with Chance Bros., Birmingham.

Work is continuing on the high intensity flash discharge lamp for colour photography, and in equipment now under extended test a flash of light of about 1/5,000th second duration is giving good results. A single lamp gives many thousands of flashes of the same light output with a spectral distribution suitable for colour photography. A low powered filament lamp for modelling is mounted integrally with the main light source and gives approximately the same light distribution. The equipment operates from the normal A.C. supply and can easily be dismantled for transporting.

AIRFIELD LIGHTING.

In spite of the development taking place in radio and radar apparatus for the use of aircraft when landing in foggy weather, visual aids remain highly desirable. Lighting equipment is still required to take over from other navigational aids a few hundred yards before the touchdown to enable the pilot to see his position and orientation relative to the runway. Absorption of light by the fog necessitates a very high intensity—up to 5,000 candles at angles up to 4° to 6° above the horizontal—to enable, say, 4 to 6 lights to be seen. Further, the intensity must diminish sharply at higher angles so that the nearer lights shall not be glaring. Scattering of light by the fog may result in a veiling haze which makes the lights more difficult to see. This effect is reduced by confining the emitted light to those directions from which it can be seen by the pilot. The combination of these two factors means that a runway light for use in foggy weather must have a high maximum intensity and a critically controlled distribution of light.

Fig. 67 shows a runway contact light designed to meet these requirements. The light is emitted through a pressed glass ring surmounting the housing, the 6 volt 36 watt headlamp in conjunction with special reflectors being sufficient to produce two high intensity beams which allow the lamp to be be seen in either direction along the runway. The whole unit is mounted in a cast iron housing, the base of which is set flush with the runway, and the glass ring is clamped between resilient gaskets. The total projection above ground level is only 2½ inches, and the contour is smooth. Further, the construction is such that the stresses set up when an aircraft runs over it are not transmitted to the glass.

Fig. 65. 2 kW tungsten filament lamp in a cinema studio unit.

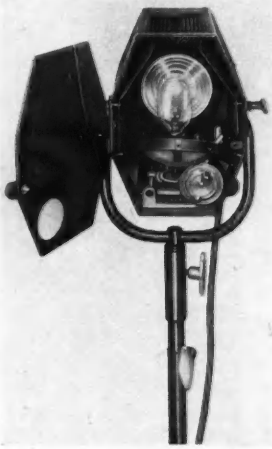


Fig. 66. 500 watt spotlight showing interior arrangement.

Although contact lights spaced uniformly along the sides of the runway give the primary means for landing, it is sometimes desired to floodlight at least part of the length of the runway. The principal requirements for such a system are that the vertical divergence shall be small, and the horizontal spread sufficient to allow the floodlight to be mounted at least 500 ft. to the side of the runway so that no shadow of the aircraft is formed on the runway at the moment of touching down.

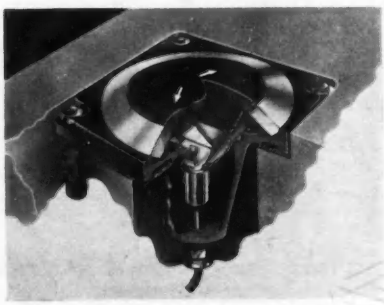


Fig. 67. Aerodrome runway contact light.

To meet these requirements, the pre-focused Osram horizon type projector lamp has again been used as the light source, since the vertical dimension of its filament is considerably less than that of any other projector lamp of similar wattage. To provide the required horizontal light distribution a special combination of three reflectors is used, in which the centre portion is a parabolic trough and the end sections are half paraboloids. The positions of the three reflectors are correctly set in relation to the lamp at a preliminary works assembly, and, as a result, both lamps and reflectors can be set up or replaced on site without further adjustment, fig 68.

The peak intensity obtainable from a single 2 kW floodlight unit is about 2·5 million candles, and a bank of three such units mounted side by side is sufficient to illuminate 2,000 yards of the runway.

STREET LIGHTING.

There have been no major advances in the theory of street lighting during the past year, but some experiments have been made in the use of low pressure fluorescent lamps which have certain advantages for this purpose ; the colour of the light is very good, and the use of large lamps, which naturally results in large low brightness lanterns, tends to reduce glare. These advantages must, however, be weighed against the high cost of equipment. It is possible that this extra expense may be justified for the spectacular

Fig. 69. Fluorescent street lighting column, Brompton Road, Kensington.

installations appropriate to the centre of London and other big towns, which can be designed for use with fluorescent lamps. Figs. 69 and 70 show respectively, one column and fitting of an installation of ten produced at the request of the Central London Electric Supply Company, and now undergoing test in the Brompton Road, Kensington. A view of this by night is shown in the frontispiece. The lighting of secondary and residential roads by fluorescent lamps is also being studied.

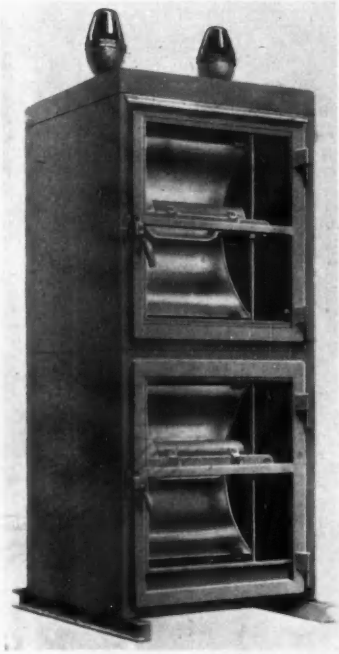


Fig. 68 Aerodrome runway floodlight

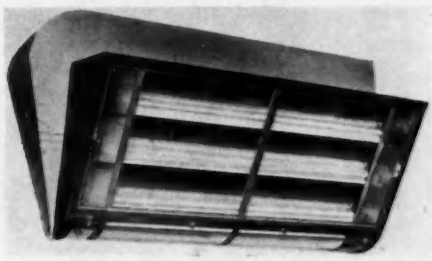


Fig. 70. Fluorescent lamp street lighting fitting.

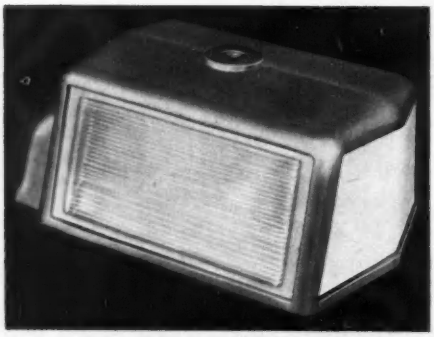


Fig. 71. Lantern for sodium vapour discharge lamp for side street lighting.

On rather more orthodox lines, there are two new lanterns of interest for side street lighting. The first, fig. 71, is for use with 45 watt or 60 watt sodium vapour discharge lamps, while the second, fig. 72, is a new type of directional lantern to take 200 watt Osram lamps, or 80 watt or 125 watt Osram H.P.M.V. lamps.

INDUSTRIAL AND DOMESTIC HEATING.

Electric Furnaces.

Many of the electric furnaces described in previous issues of the G.E.C. Journal have quickly become established as standard patterns in their particular fields.

New types produced during the year include a rotary hearth furnace for heating brass billets to 850 degs. C. prior to extrusion (fig. 73). This furnace has a hearth 1 ft. 4 ins. wide with a mean diameter of 5 ft. 9 ins. and a clear loading height of 1 ft. 6 ins. It has three element zones, two for heating and one for holding, which are regulated separately and automatically. Photocell controllers indicate the arrival of a billet at the discharge station and automatically stop the rotation of the hearth.

The batch furnace shown in fig. 74, is used for annealing thin aluminium sheet coiled on steel spools. Fans in the heating chamber, which measures 3 ft. 6 ins. wide by 2 ft. 3 ins. high by 8 ft deep, accelerate the heating of the charge and ensure a uniform temperature distribution. A continuous flow of work is provided by a mechanically operated double-type charging machine on which the steel spools are suspended horizontally.

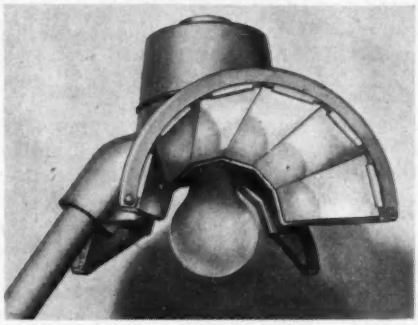


Fig. 72. Directional reflector for side street lighting.

Further work has been done in investigating and developing the use of controlled atmos-

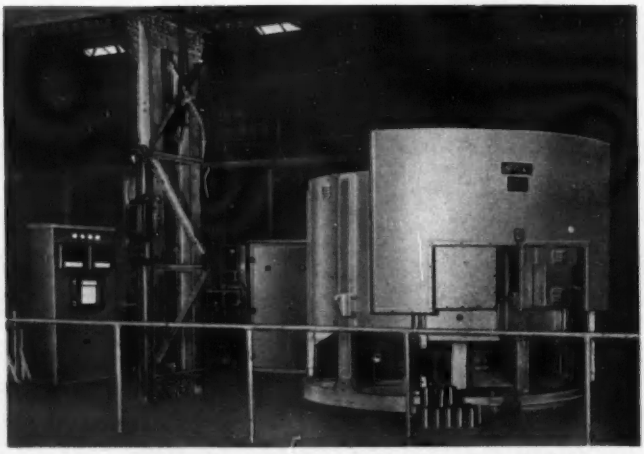


Fig. 73.—General view of a 175 kW rotary hearth furnace preheating brass billets at Earle Bourne & Co., Ltd., Birmingham.

pheres, particularly for gas carburising and gas malleablising processes. Much progress has been made in both these fields.

Radiant Heating.

In radiant heating, as in other branches of process heating, development has included the investigation of specific industrial applications as well as the design of new equipment.

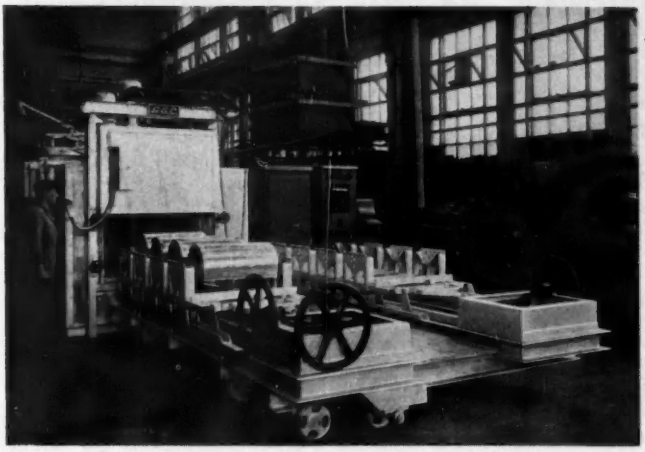


Fig. 74.—56 kW batch type annealing furnace for aluminium at Venesta Ltd., India, with door open and a charge of coils entering the furnace.

The stoving of paint still attracts much attention, but interest now centres in decorative finishes rather than the drab camouflage of wartime. Many problems have come from the motor car industry, among them, the stoving of complete bodies. The plant in fig. 75 is used for simultaneously stoving primer-surfacer and stopper on a well-known coupé body, before applying the cellulose finishing coats. It handles one body at a time, and stoving is complete in 20 minutes.

The softening of Perspex sheet, before it is shaped by pressing or blowing, is an important use of radiant heating in the plastics industry. The plant in fig. 76 is one of several used in a large factory which produces articles ranging from wash basins to small ornamental bowls.

The medium intensity oven shown in fig. 77 has been introduced during the year to fill the gap between lamp equipment and the high intensity ovens developed during the war for stoving paint on artillery shells. It is built in standard 3 ft. 6 ins. sections, with double-walled lagged steel casings. Panel type heating elements are mounted on the walls of all except the end sections which are fitted with baffles to reduce the loss of heat through the open ends of the oven. Articles pass through the oven on an overhead conveyor. As the radiation from the relatively low temperature elements is of longer wavelength than that from lamps, it is more readily absorbed by articles light in colour.

The principal use for this type of oven is for stoving paint rapidly on fairly massive articles.

High Frequency Heating.

Few of the many applications of high frequency heating investigated during the year have proved straightforward. Models of the various standard generators have been installed at the Research Laboratories for this work, and investigations have been undertaken in collaboration with firms specialising in types of production for which high fre-

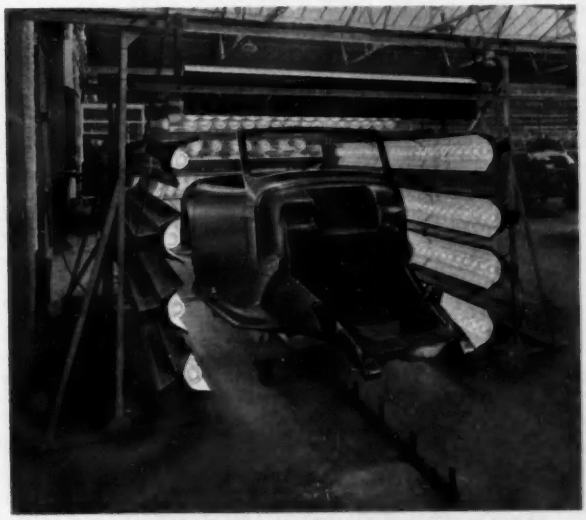


Fig. 75.—Stoving the paintwork on a car body by means of radiant heat.

Fig. 76.—Radiant heating equipment being used to soften "Perspex" sheet.

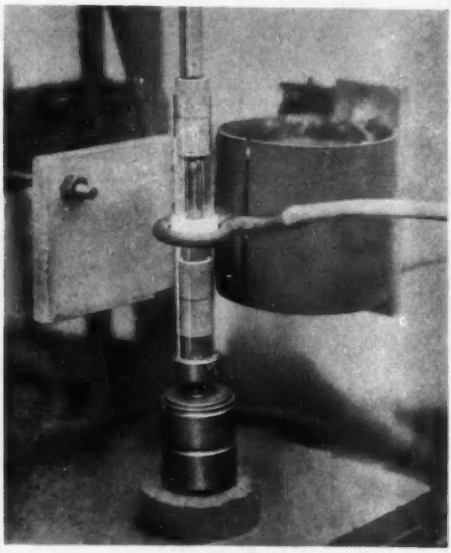


Fig. 78.—Eddy current heating equipment being used to make a copper-to-glass seal.

quency heating appears to offer special advantages.

These investigations have included numerous examples of the application of eddy current heating to the surface hardening of steel components for motor car engines and transmission systems, brazing, soldering and melting processes, and the manufacture of glass-to-metal seals. In one interesting problem, it was required to heat a non-metallic material to a temperature of over 2,000 degs. C. The material was heated by eddy currents induced in a lagged graphite crucible, supplied with a neutral atmosphere. In the course of laboratory experiments, a temperature of over 2,500 degs. C. was reached. Fig. 78 illustrates the use of eddy current heating for making copper-to-glass seals for radio valves. Currents induced in the copper disc heat it sufficiently to cause local melting of the glass tube which flows and becomes sealed to the disc.

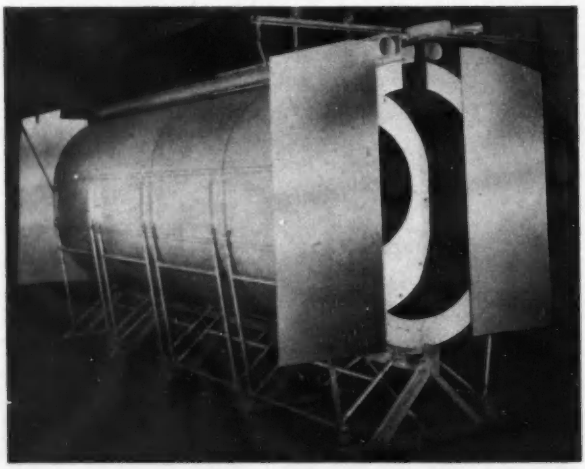


Fig. 77.—Medium intensity radiant heating oven.

A wide range of applications of dielectric heating has also been covered, including the drying of sponges and of thread on spools, the sterilisation of lint after packing, the heat treatment of tobacco and rubber, and the pasteurisation of beer after bottling. The more straightforward applications to wood gluing and the pre-heating of plastics have also received their share of attention.

Numerous improvements have been made to the circuit arrangements of the standard production gener-

ators to increase their efficiency, and new models of different ratings are being developed.

When high frequency heating is put to use in a factory it is almost as important to have efficient work-handling equipment as to have an efficient generator. Much attention has been given to this aspect of the work so that complete installations can be supplied for both eddy current and dielectric heating.

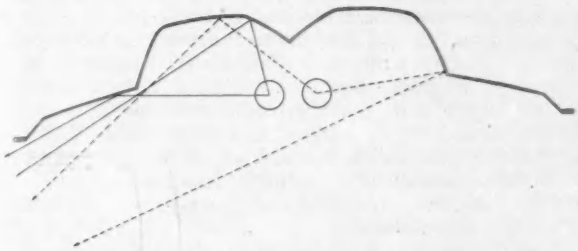


Fig. 79.—Diagram of multiple parabola wide-angle reflector.

Domestic Appliances.

A complete new range of domestic appliances has been designed and manufacture will be proceeding on a large scale within the next few months. The new models are more pleasing in appearance than those made before the war. At the same time, they have been improved technically and their manufacture has been simplified. Prototypes of six of these appliances were selected by the Committee appointed by the Council of Industrial Design for inclusion in the recent "Britain Can Make It" Exhibition.

Several new fires have been designed, incorporating a new type of reflector which gives a more uniform distribution of radiation than was obtained with pre-war fires. The reflector consists of a number of sections of parabolas which direct the rays into the paths shown in fig. 79. As can be seen from the radiation distribution curve given in fig. 80 the reflector gives an almost constant distribution of intensity over an angle of 120°. The distribution curve obtained with a typical pre-war reflector is also given in fig. 80 for comparison. One example of this range of fires is shown in fig. 81.

The cooker shown in fig. 82 makes a clean break with pre-war practice. It occupies no more space and weighs less than earlier "small" cookers, but has oven and hob equipment previously found only in "medium" models. These improvements have been made possible by using sheet metal in place of cast iron and by fitting sheathed wire oven elements which are less bulky than the usual pattern with ceramic formers.

Development work on thermostats has centred on models incorporating snap-acting

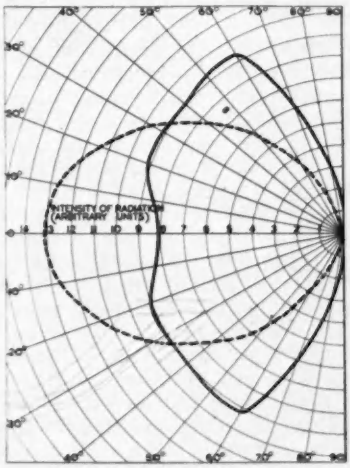


Fig. 80.—Distribution of radiation in a horizontal plane :—
——New fire with vertical elements and wide angle reflector.
- - - -Typical pre-war reflector fire.

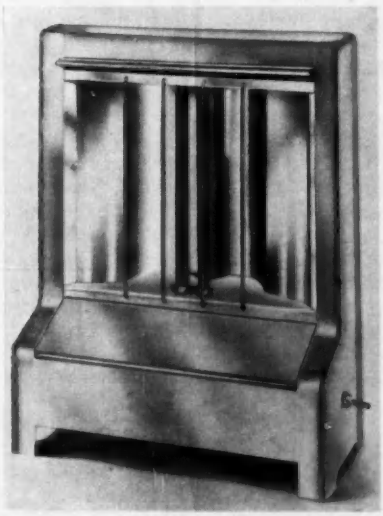


Fig. 81.—One of the new electric fires with wide angle reflector.

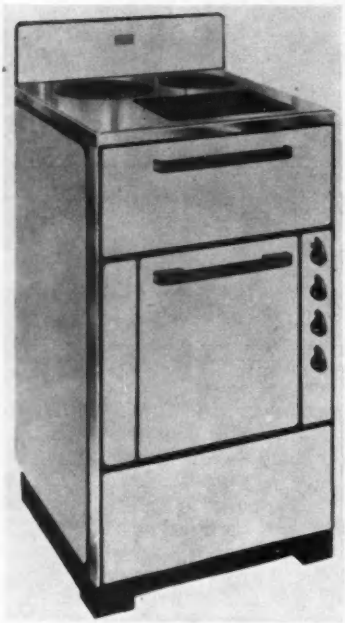


Fig. 82.—New domestic cooker as exhibited at the "Britain Can Make It" Exhibition, London.

bimetallic discs. Two motor protection thermostats of this type have been introduced, one with manual and the other with automatic resetting. The adjustable space-heating thermostat shown in fig. 83 incorporates a single pole two-way switch mechanism and is therefore suitable for use in air conditioning systems.

AGRICULTURAL AND HORTICULTURAL HEATING.

A range of step-down transformers for use with low voltage bare conductors for soil heating has been introduced and installations covering areas varying from a few square feet in a light garden frame to over an acre are in operation.

The continued importance of harvesting the maximum amount of home-grown grain has fully justified the attention which has been given to the design of electric heating units for grain dryers. Technical developments have now made possible not only a better product by improved temperature distribution within the drier, but fully automatic operation and reduced maximum loading. A new conversion unit, to take the place of

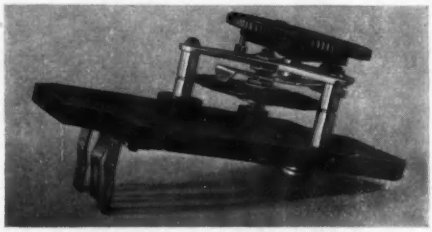


Fig. 83—The new air thermostat.

the fuel fired heater in a well-known make of dryer, has been introduced during the year. It comprises a battery of four 33 kW heaters, each controlled by one step of a four step thermostat, and is complete with the necessary control equipment.

Applications of Radio Technique to General Measurements.

By G. R. POLGREEN, M.B.E., B.Sc., M.I.E.E.,
Salford Electrical Instruments, Ltd.

Radio, originally a subject confined to communications, has now extended into other fields, notably Measurements. Recent radio developments have important applications to instruments for use in the electrical industry, and considerable possibilities for measuring and control equipment for use in most other industries and peace-time activities. These are summarised in the address given recently to the Radio Group of the Institution of Electrical Engineers, in Manchester.

INTRODUCTION.

WHEN the Wireless Section of the Institution was formed over 25 years ago, after the end of the first World War, radio technique was a subject somewhat remote from the rest of electrical engineering practice and even from the allied subjects of line telephony and telegraphy. The frequency gap between these groups was, however, quickly closed by the rapid development of multi-channel telephony in the 1930's, and now the further rapid strides during the war years, together with the extension of the practical frequency range up into thousands of megacycles, have merged these various branches of electrical signalling into one compact subject, telecommunications.

At the termination of the Second World War, radio engineering has achieved the stature of a major industry with importance recognised by all, and with a responsibility to the community probably as wide as that held by the whole Institution in the early years of this century. This address is presented at a time when the thoughts and efforts of a large proportion of the members of the Radio Groups of the Institution are directed towards the conversion of their war-time developments and extended manufacturing facilities to peace-time uses. The importance of telecommunications here needs no emphasis, but radio technique, which is the basis of these activities, also has an ever-growing application to other branches of electrical engineering, especially to the subject of another specialised group of the Institution, namely, Measurements. The subject chosen for this address is, therefore, the application of radio technique to measurements in the field of electrical engineering other than the radio sphere, and also to the numerous measurements problems associated with industry generally.

In the limited time available it is only possible to summarise the significance of certain war-time developments in regard to the field of industrial measurements, and a number of electronic instruments will be briefly described as illustrations of the extensive possibilities of the various applications of radio technique.

It is not generally appreciated that the developments of radar during the last seven years or so have introduced a specialised branch of Measurements on a large scale into the orbit of radio engineering. The normal telecommunication circuit, which has hitherto been the basis of radio, consists of a transmitter and receiver which are separated geographically but which are connected either by electro-magnetic waves transmitted through the intervening space, or by a wire or wires in the case of line telegraphy and telephony. Radio direction finding is, of course, not new and had been used for many years before the recent war by means of directional or controlled receiving aerials in order to obtain the bearings of the receiver in relation to the transmitter. Radar is fundamentally different from this arrangement; it consists, in essence, of a single station which can obtain direction and distance in measurements in relation to inanimate objects, or their equivalent in warfare, enemy aircraft, ships or vehicles. It is true that the term "radar" has been used in a wider sense for such applications as navigational aids based on resultant measurements of the transmissions from two or more radio transmitters, but the basic requirements which are usually described as "radio direction

finding and ranging" can be met by an electrical instrument which measures the distance of any desired object within the range of the equipment, and also gives its position in terms of elevation and bearing. Thus, a basic radar unit is, from the application standpoint, a type of universal surveying instrument with the advantage that it will operate under conditions of low or zero visibility.

The radar principle of high frequency reflected waves operating an electrical instrument calibrated in terms of distance, was already in use before the recent war in an aircraft instrument known as the Terrain Clearance Meter. This showed the height of the aircraft above land and in conjunction with the altimeter would enable the pilot to deduce the height above sea level of the ground beneath him. Details of this system were published in the Bell System Technical Journal in America just before the war, in January, 1939, by Espenschied and Newhouse.

PRACTICAL CONSIDERATIONS.

The name "electronics" indicates the functional basis of most of the radio devices which can be applied to the various kinds of instruments, namely, thermionic valve, cathode ray tubes, certain types of photocell and similar apparatus. It is advantageous at the outset to examine the criticisms and alleged disadvantages of equipment and instruments incorporating such components, because they have tended to limit their use in the past both by users in the heavier electrical engineering branches and in the non-electrical fields of application.

These criticisms have been mainly :—

(i.) that such electronic instruments and equipment are bulky, fragile and require careful handling, especially since some of the most important components are housed in glass envelopes.

(ii.) that thermionic valves of any type can vary considerably from their normal performance and thus are unsuitable for exact measurement purposes, and involve difficulties in maintenance and replacement.

(iii.) that all electronic equipment requires external power supplies. When batteries are used, they are bulky and require frequent replacement and adjustment; when the equipment is to be operated from the electricity supply mains, there is the encumbrance of trailing leads and the necessity of dealing with the many types of supply throughout the world.

(iv.) that engineers skilled in the theory and practice of electronics are required to operate such equipment, which obviously would present difficulties in non-electrical industries.

Most of these criticisms can be met by consideration of experience obtained during the war. Every fighting ship, aeroplane and land vehicle contained radio and radar equipment of greater complexity than the majority of existing or projected electronic instruments. Due to the prevailing man power shortage, the war-time radio and radar apparatus was operated and kept in running order by men and women who generally had no previous experience and limited training. Moreover, it has recently been disclosed that many of the operating mechanisms in bombs, rockets and even shells were based on the use of thermionic valve equipment and associated power supplies built into these weapons. Perhaps the best example is the proximity fuse built into the extremely small space in the nose of an A.A. Shell. This is, in essence, an electronic instrument for the indication of a predetermined distance between bodies, one of which is moving.

While the thermionic valve can be used satisfactorily and reliably in war-time conditions of extremely short operating life, it can also be used continuously in totally inaccessible positions for many years, as in the case of the underwater repeater for telephone cables which operates at the bottom of the ocean.

Since these thermionic valve-operated equipments have withstood the shock of bomb and shell, and have been used in all parts of the world under the worst terrestrial conditions, it is safe to assume that they will operate satisfactorily in ordinary industrial conditions or even in the hands of farmer, miner, doctor or housewife if they should achieve such universal use.

The question of power supplies is becoming simplified by the standardising of A.C. mains voltage and frequency and, where batteries are required, recent developments have resulted in a great reduction in battery size with improvements in stability, capacity and life. Where necessary, portable instruments can now be made to operate from either mains or batteries without undue increase in size or weight.

With regard to the possibilities of the use of the thermionic valve as a precision com-

ponent for measurement purposes, great advances have been made during the past ten years, largely as a result of the development of feedback circuits and other devices which result in high stability amplifiers which are largely independent of the actual characteristics of individual valves. Also extensive research and development work is constantly being carried out by makers of thermionic valves both in the design and performance of the individual valve and its applications to all types of circuit, so that especially stringent requirements can often be met by close co-operation between the equipment designer and the valve manufacturer.

ELECTRICAL MEASUREMENTS.

All electrical engineers are well acquainted with the basic methods of measurement of their fundamental units: voltage, current resistance, etc., and these methods and the instruments associated with them have changed very little since the early days of electrical instruments. For example, the moving coil has altered very little in construction since it was first developed, and the endeavours of instrument designers have been directed towards improvement in accuracy, robustness and range, largely by the applications of new materials, such as the latest types of permanent magnet, and by new methods of manufacture.

Thus, small two-pivot type instruments of first grade accuracy will read down to full scale values of 50 or 100 micro-amperes, and while this sensitivity will meet a large proportion of the general uses of electrical instruments, there are many cases where much smaller currents must be measured with speed, accuracy and convenience. The next order of sensitivity of a few micro-amperes is met by the use of single pivot instruments, and for smaller currents down to micro-amperes there are several types of galvanometer mostly using a reflected beam of light and requiring considerable care to prevent vibration and to ensure accuracy.

This range of instruments will, of course, only operate with direct current and, for the wide range of A.C. measurements now required, it is necessary to use conversion units such as open or vacuum types of thermo-couple unit, bridge type metal rectifiers, thermionic valve detectors, and, for very high frequencies, crystal detectors. It is evident that there is a requirement for an absolutely stable amplifier of compact dimensions which will amplify A.C. or D.C., the output of which can be fed to a moving coil instrument. Now the application of the thermionic valve as an amplifier has been known for 30 years and its importance to telephony and radio needs no emphasis here, but it is only during the last ten years that the development of the feedback principle has resulted in the design of amplifiers which are stable enough for instrument applications. Thus in some cases an amplifier detector instrument can be calibrated direct in the quantity it is used to measure, but the use of a built-in amplifier, as a means of improving the sensitivity of a moving coil instrument, can be regarded as being at present in the development stage only.

There are, however, several possibilities in the use of amplifier detectors in bridge circuits for the measurement of null points, and these frequently use indicating instruments as the means of detecting balance, but it is convenient to use a device of the "electric-eye" type in some cases. This is of special importance for radio frequency bridge measurement in which a telephone is used for balancing the bridge, with the accompanying inconvenience of use and the need for a specially quiet room in which to make the measurements. Similarly bridge tests at higher frequencies such as are used in the manufacture of carrier telephony cables, inductances and their components, hitherto utilised heterodyne detectors with audio detection by means of a telephone. The use of visual detection is of special importance in the factory and the field, though care must be taken to minimise harmonics which can be distinguished by the ear but tend to introduce inaccuracy and lack of sensitivity in visual detection.

VALVE VOLTMETERS.

The conventional switchboard and portable voltmeters used in such large numbers in all branches of electrical engineering are essentially current-measuring devices in which as high an impedance as possible is obtained by the series connection of resistances to a sensitive ammeter. While this method is quite satisfactory for circuits where there is adequate power available, errors are introduced into the results in the case of sensitive measurements where the power taken by the meter is an appreciable proportion of the total power available. The valve voltmeter enables good sensitivity to be obtained with input impedance many times higher than that of other types of instruments. So that there shall be a minimum disturbance to the circuit when the valve voltmeter terminal is con-

nected to it, the valve is often housed in a small head so that the grid connection is extremely close to the point of application of the circuit to be measured. A flexible cable supplies the power to the valve, and connects it to the main part of the instrument.

A typical general purpose valve voltmeter

Fig. 1.—BW. 211 General purpose valve voltmeter.

is operated from the A.C. mains and can be used to measure in the range of 50 cycles to 50 Mc/s with an accuracy of 2 per cent of full scale reading of all ranges with a true sine wave input. It has five ranges from 1·5 volts to 150 volts full scale deflection, and the variation of reading over the specified frequency band is less than 1 per cent. The input impedance is approximately 1 megohm at 1 Mc/s and the input capacitance is about seven micromicrofarads.

The detecting valve is a diode, the output from which is connected to a D.C. amplifier connected in a bridge circuit such that the out-of-balance current indicates the voltage. (fig. 1).

Such an instrument reads peak voltage although it is calibrated in r.m.s. values on the assumption of a sine wave-form and account must be taken of these facts if distorted wave forms are being measured.

There are various other types of valve voltmeters used for special purposes, especially at higher frequencies, but for general purposes a small battery operated type can be used where the sensitivity and accuracy are not so important. This instrument uses a simple battery-operated triode arranged as a diode. A small battery is contained in the box and there are three ranges with full scale values of respectively 5, 25 and 100 volts. This instrument will read up to 5 Mc/s with an accuracy of 2 per cent (fig. 2).

Due to the saturation feature of valves, all types of valve voltmeter will withstand overloads to a much greater extent than any other type of instrument. By the use of suitable amplifiers wide ranges of sensitivity for the measurement of A.C. voltage are already possible, for which there are no other methods of measurement available. The properties of the valve can also be used to modify the scale shape from approximately linear to logarithmic or to obtain a linear decibel scale. High voltages up to 10 kV or more can be measured by using a capacitance divider with the valve voltmeter.

MEASUREMENT OF CURRENT.

The usual method of measuring current is either by its magnetic or by its heating effect, and the latter becomes more important for higher frequency conditions. Electronic circuits can be used to measure current indirectly by the measurement of voltage across a known resistance through which the current has passed. This method is especially applicable where the current value is small and where it is possible to use a comparatively high resistance. In these instances the conventional

Fig. 2.—Small battery operated BW. 218 valve voltmeter.

types of valve voltmeter can be used, and modifications of this class of measurement can be applied to the measurement of small power values.

RESISTANCE MEASUREMENTS.

By using a modification of the method just described, it is possible to measure resistance values, especially high resistances of the order of many megohms. The "megger" is familiar to all and it is difficult to improve upon so handy and compact an instrument for general insulation testing, but such an instrument has the inevitable limitation of sensitivity and is unsuitable for the insulation resistance values which must be measured in such instances as telephone cables and loading equipment and which extend to hundreds of thousands of megohms. The laboratory and works test for such insulation values has, hitherto, consisted of a high voltage battery

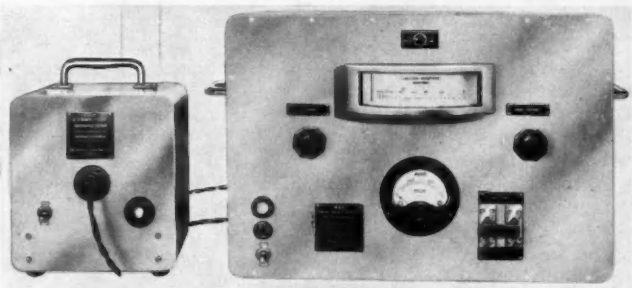


Fig. 3.—Insulation resistance meter.

connected through a standard resistance to a very sensitive mirror galvanometer; the series standard resistance and the corresponding galvanometer reading can be read in terms of megohms. An electrical instrument, operated from the A.C. mains, supplies a fixed D.C. voltage to the test resistance, and the associated valve voltmeter circuit can thus be calibrated directly in thousands of megohms. Such instruments can be battery operated in order to make tests in the field or in buildings where mains supplies are not available (figs. 3 and 4).

WAVE FORM.

The cathode ray oscillograph is too well-known to warrant detailed description here but it has hitherto been a somewhat bulky instrument chiefly suitable for laboratory tests. The size of the equipment largely resulted from the use of large C.R.O. tubes in order to give a trace great enough for accurate measurements. The small tubes, however, now give such good definition that a miniature equipment with 1½in. diameter tube is almost as useful as the larger types and has the advantage of being as handy as a portable moving coil instrument. Such a miniature oscilloscope can be made of size only 9ins. × 6½ins. × 2½ins. and the equipment can be operated from A.C. mains or from a 12 volt battery and vibrator. By the use of an external lens housed in a hood it is possible to obtain the effect of a 3in. diameter tube (fig. 5).

INDUCTANCE AND CAPACITANCE.

There are many ways of measuring these properties dependent upon the range and magnitude of L or C and the power factors involved. Most of the methods hitherto used have been of a laboratory or test-room nature which consist of an assembly of a number of separate units—generator, bridge or resonance circuits, detectors, power supplies, which would be difficult to use under many industrial conditions. Modern electronic equipment enables all these units to be built into one compact instrument, and the measuring instruments can be calibrated directly in any required unit to be measured; alternatively, such equipment can be used as comparators in checking a large number of

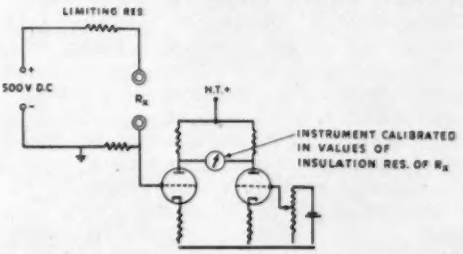


Fig. 4.—Simplified diagram of insulation resistance meter.

components against a standard. In the latter case, indication can be arranged by means of a "magic eye" type of electronic detector.

Equipment involving L and C measurement has considerable applications for the measurement of the various properties of metals and dielectrics in the industrial field, and this can be made the basis of a large group of industrial measuring equipment.

FREQUENCY.

With the very wide range of frequency values employed in electrical engineering to-day, it is important that there shall be quick and accurate direct measurements of

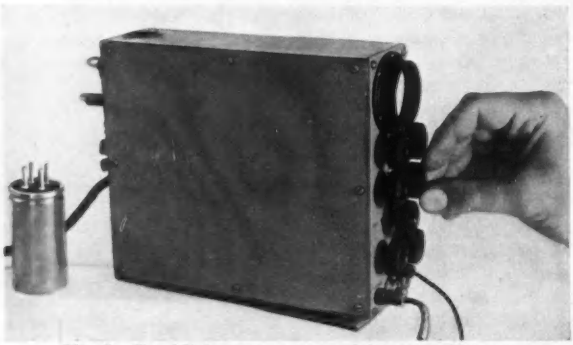


Fig. 5.—The Miniscope: a new miniature oscilloscope.

frequency available. For radio applications there is a wide range of such equipment as wavemeters and signal generators which require some skill or knowledge to use. Indicating instruments have recently been developed which can give direct measurement over a wide frequency range. An example of this is a direct reading instrument which covers the audio and supersonic range up to 45,000 c/s in four ranges, the lowest being 0 to 120 c/s (fig. 6).

The accuracy to which frequency measurements can be standardised and controlled to-day is largely the result of the very rapid growth in the development and manufacture of quartz crystals during the last ten years. Whilst there is now enough information on this subject to fill several text-books, it is sufficient to state that a simple mass-produced quartz oscillator in the form of a portable instrument can now give an accuracy for fixed frequencies of a few parts in a million without special temperature controlled devices. There are, however, many new developments in the production of quartz crystals themselves, as a result of the cutting of quartz to certain optimum angles relative to the three axes, which will give appreciably greater accuracy than the figure quoted (fig. 7). For the low and medium frequency types, improved performance and reliability is obtained by metallising the crystals and using soldering methods to support the unit in a glass envelope similar to a thermionic valve. This type of construction is very suitable for quartz crystals in frequency standards which are generally designed to operate at 100 kc. (fig. 8).

The associated oscillator is coupled with additional equipment obtaining multiples and sub-multiples of the standard frequency and in addition an electric clock is used to check the frequency accuracy over long periods of time. The clock, which is driven from a low frequency controlled by the frequency standard, integrates the frequency over a measured period of time and, by comparison with standard time signals, enables very great accuracy in frequency measurement and comparison to be obtained. Using the latest type of crystal with suitable thermostat devices, a frequency standard can be made with long term accuracy of 1 part in 100 million, which is about the most accurate measurement that it is possible to make. In any form of instrument it is thus convenient to refer all other types of measurement back in terms of frequency in order to take advantage of the simplicity of comparison and extreme accuracy now available.

This subject also introduces the accurate measurement of time, one of the earliest and most fundamental measurements in the world. Quartz crystals can now be made which oscillate at frequencies in the audio frequency range and the output can be fed direct to a special electric clock without the use of further valve circuits. Since there are 31 million seconds in a year, the crystals referred to, associated with a thermostatically controlled mains-operated oscillator, can impart to an electric clock an accuracy of a fraction of 1 second

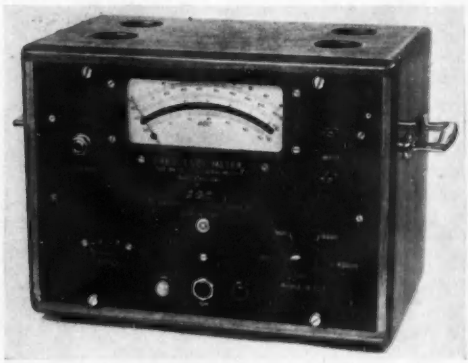


Fig. 6.—Electronic frequency meter.

per year. A number of these high accuracy quartz clocks have been installed at the Observatory at Greenwich and have made precision mechanical clocks obsolescent.

Commercial clocks with somewhat less

accuracy but much more accurate than any purely mechanical device are now a manufacturing possibility, but it is important, however, that some automatic method be provided for maintaining the oscillator current in the event of interruption to the mains supply, because even a momentary break in the A.C. supply will upset the basic accuracy of the clock.

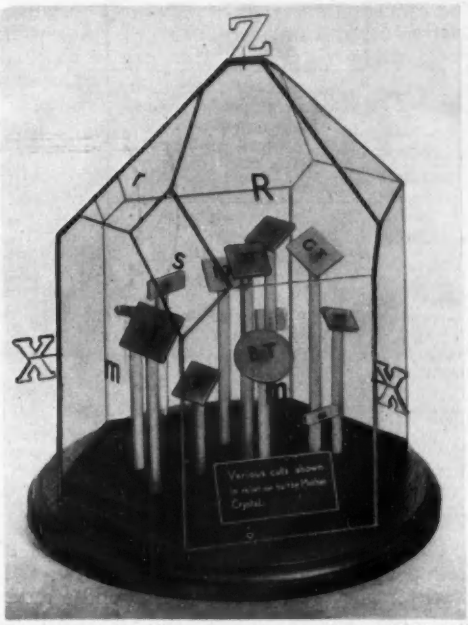


Fig. 7.—Model to illustrate various quartz crystal "cuts" for a range of electrical applications.

NON-ELECTRICAL MEASUREMENTS.

As mentioned earlier, there are so many applications of electronics to industrial processes that it is only possible to mention some of the more important groups and in this category comes the electrical non-destructive testing of materials. All materials have special electric and magnetic properties which bear some relation to their physical properties, chemical composition and numerous other characteristics. Most magnetic and electrical tests can be carried out on materials and manufactured parts without impairing their properties, whereas chemical and mechanical testing results in permanent damage to the samples tested. It is thus possible to devise electrical or electronic instruments to carry out 100 per cent testing of materials and manufactured parts for a considerable proportion of materials used throughout industry.

Table I shows the electrical and magnetic properties of materials which can be applied for this non-destructive testing.

By the measurement of the magnetic properties of steel rod, for instance, it is possible to obtain, on a comparison basis, with a standardised sample of the same material, information concerning its hardness, composition, heat treatment, etc. Similarly, the measurement of the dielectric loss and permittivity of chemical substances will give valuable data regarding their purity, composition and physical properties. The comparison sample in each case must first be thoroughly tested under laboratory conditions to ensure that it

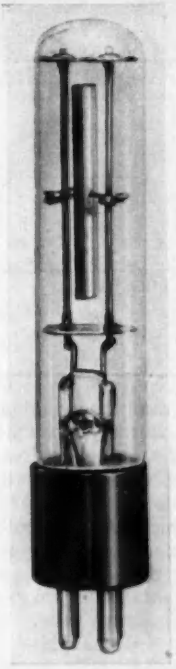


Fig. 8.—Quartz crystal unit in glass envelope.

is representative of the desired quality of product, and it is essential that there shall be a correct correlation between the properties it is desired to measure and the corresponding electrical or magnetic characteristics. In addition to the advantage of 100 per cent testing, the electrical instrument used in this type of work can be operated by unskilled labour and frequently can be made automatic.

The magnetic sorting bridge is an example of the practical application of this principle of non-destructive testing (figs. 9 and 10). This instrument was developed in conjunction with the makers of aircraft engines to test the metal parts,

especially valve springs, valve rods, connecting rods and other moving parts which are so vital to the performance of high speed internal combustion engines, especially in view of the increased reciprocating speeds and the importance of cutting down weight. The parts to be tested are placed successively into one of a pair of accurately matched coils connected to two similar accurate resistances in a bridge circuit. The other coil contains the standardised master sample and the circuit is fed from 50 cycles A.C. mains. The current is adjusted so that the test pieces are subjected to a degree of magnetisation approaching saturation, and the output from the bridge is connected through a high gain amplifier to a cathode ray tube.

If the testing pieces and master are of similar composition and physical properties the hysteresis loops will be similar and the resulting trace on the tube will be a straight line; if there is a difference, however, the tube will show a distinctive trace, the shape of which will depend on the extent of the difference in physical or chemical properties and on the point of the cycle at which this dissimilarity occurs.

This machine has applications to the testing of materials and parts of all types of steel and its sensitivity can be made so great that it will detect the difference in strain between two household pins. It can thus also be used for the detection of small magnetic or metallic impurities in non-metallic parts, such as plastics, textiles or wood.

TABLE I.

Group	Electro-Magnetic Property	Applications
1. Conductors.	Resistivity. Para- or Dia-Magnetic.	Measured by D.C. (fixed sample) or A.C. (continuous testing) for structural uniformity or thickness of sheet, foil, etc.
2. Magnetic Materials.	Permeability. Incremental Permeability. B–H Curve. Hysteresis Loop. Remanence. Coercivity. Saturation Flux. Magnetostriction. Resistivity.	Structural uniformity. Air gap length or layer thickness. Metallurgical properties. Shape of loop denotes hardness, grain size, heat treatment, strain, composition, etc. See 1.
3. Insulators.	Permittivity. Dielectric Loss. Resistivity.	Testing of purity and composition of non-metallic materials, liquids, chemicals, etc.

For all types of metal-using industries it is important to be able to measure flaws and cracks in metal bar stock or wire, and a radio frequency crack detector can be used to detect and locate such faults. This can theoretically be arranged by the use of a direct current test but this involves difficulties

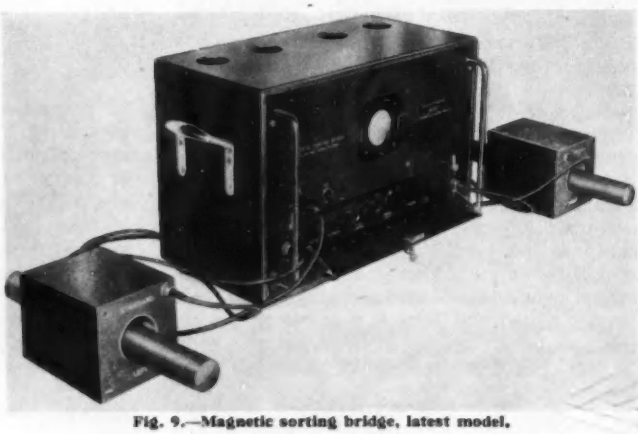


Fig. 9.—Magnetic sorting bridge, latest model.

in making the necessary electrical contacts. By using the principle of the eddy-current loss developed in a coil carrying high frequency current, which surrounds the test piece, and by comparing it with the perfect specimen of a similar metal part, it is possible for large quantities of metal to be tested in a comparatively short time. It is generally only necessary to have a simple detector such as a lamp or a buzzer and the equipment can be made fully automatic by spraying paint on the parts of the metal rod or bar which contains the cracks (fig. 11).

The subject of vibration in all types of rotating machinery, especially in internal combustion engines, is of great importance and before curing the cause of such vibration

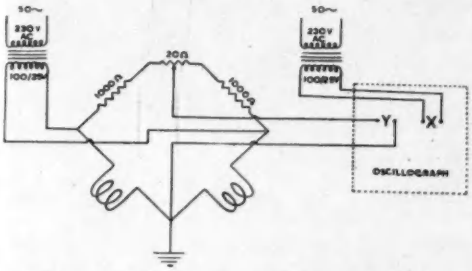


Fig. 10.—Simplified diagram of magnetic sorting bridge.

it is necessary to detect it and obtain a measurement of the approximate frequency and amplitude. By means of a piezo-electric crystal, which transfers the vibration to electrical impulses, it is possible to measure on an indicating instrument the intensity of vibration at different parts of the machine,

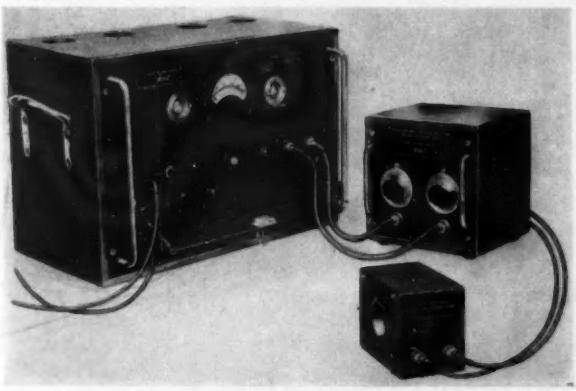


Fig. 11.—Electronic crack detector.

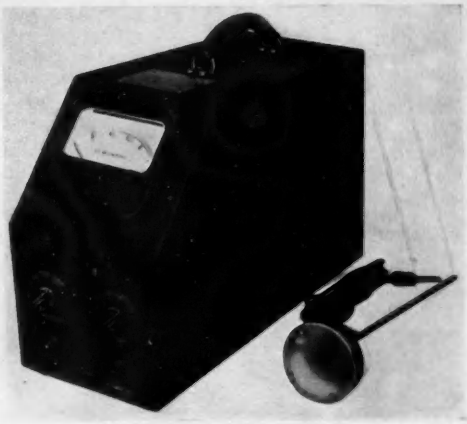


Fig. 12.—Vibration analyser.

and the use of electric filter circuits gives the approximate frequency range. This instrument gives valuable data to the tester of the actual point in the machine at which the vibration occurs and the predominant frequency will indicate the part of the machine responsible for that vibration (fig. 12).

In rolling mills for making thin sheets and foils, it is difficult to use a mechanical system to indicate the thickness of stationary samples or while rolling is in operation. Here again electronic equipment can be used to give continuous indication of the foil thickness without contact between the metal and the measuring head of the test instrument. It depends for its operation on the fact that eddy-current losses vary with the cross section of the material if the conductivity is kept constant (fig. 13).

There are several uses of photocells and associated amplifiers for various types of electrical and industrial applications, such as the measurement of colour, gloss and similar properties. Counting operations on the principle of the interruption of a beam of light directed on to a photocell are already well-known and in widespread use. Typical of the new development employing this principle is a method of measuring the trueness of periphery and width of gap, of a specific size of a piston ring. The ring to be checked is inserted in a master ring and the difference in contour and size is apparent by the amount of light

passed through the intervening space. By scanning this light and using photocells, it is possible to arrange a series of signal lamps to indicate on a "Go" and "No Go" principle. Similar methods can be used to check the shape of any parts or components which must conform to an accurate pattern.

There are innumerable other applications of radio technique to mechanical engineering, such as the measurement of indicator diagrams for internal combustion engines by means of piezo-electric crystals housed in a special holder screwed into the cylinder head. The smoothness of metal surfaces, such as cylinder bores, can be measured by a type of sound-reproducing "Pick-up" drawn over the surface. Strain in structures and pressure can be measured electronically with all the advantages of remote operation and indication.

Now electronic equipment is finding numerous applications to the chemical and foodstuffs industries, and to farming and geological activities. More recently, the medical profession has found many uses for high grade amplifiers and other high frequency apparatus which add greatly to the already extensive use of electricity in medical equipment.

In all these examples of instruments which are required for non-electrical uses, it is important to refer to the many advantages obtained by the use of electrical instruments and equipment in comparison with other methods. In particular, mention should be made of the possibilities of recording, automatic operation, remote control and indication, and simplicity of use. All these merits are well-known among electrical engineers, but are not always appreciated elsewhere.

CONCLUSION.

To summarise and conclude this address it is desirable to consider the present stage of development of electronic instruments and to indicate the progress to be expected in the future. The extension of radio technique during the war has been unprecedented, but most of the applications have been confined to the urgent demands of defensive and offensive warfare and much work must be completed before the full benefits can be applied to industrial and other conditions.

Many public speakers have given the impression that such war-time developments as radar have immediate and widespread peace-time uses, but the facts appear to indicate that they will be confined to certain aspects of sea and air navigation. Simpler, cheaper and more compact devices are required for corresponding land transportation problems and there is a need for electronic instruments of many types, most of which have still to be developed.

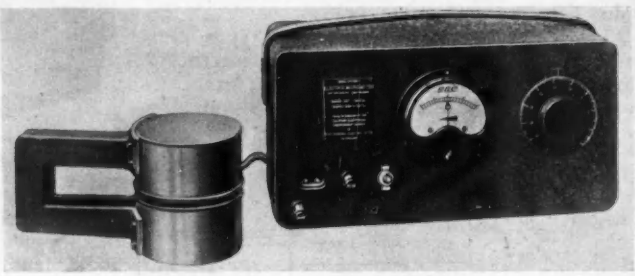


Fig. 13.—Metal foil thickness meter.

Many of the instruments in this address have necessarily been chosen from the author's experience, but it is hoped that they have been representative enough to indicate the principal conclusions, that there are latent applications of radio technique to all kinds of testing and measurement and also to the improvement of design of a large number of existing instruments. It is desirable to add a warning, especially regarding the non-electrical applications, that the chief problems associated with many of the new developments are more concerned in the application rather than in the basic design. It is not always difficult to make instruments which can give adequate sensitivity for the purpose in view, and a considerable mass of data, curves and figures can be obtained. It is of the highest importance that these shall be correctly interpreted and that full consideration is given to the different variables which may be operating. These problems can be solved by research and development work, together with close co-operation between the electrical engineer and the many specialists in the various industries for which these new electronic instruments have been produced.

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